TRANSACTIONS

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW ZEALAND

VOL. 74
(QUARTERLY ISSUE)
PART 1, JUNE, 1944

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OF THE ROYAL SOCIETY OF NEW ZEALAND

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PROCEEDINGS

OF

THE ROYAL SOCIETY OF NEW ZEALAND

MINUTES OF THE ANNUAL MEETING, 17th MAY, 1944.

THE ANNUAL MEETING of the Council of the Royal Society of New Zealand was held on Wednesday, 17th May, 1944, at 10 a.m., in the Council Room, Victoria University College, Wellington.

The President, Dr. H. H. Allan, presided.

Present: The President, Dr. H. H. Allan; the Vice-President, Dr. P. Marshall; representing the Government—Dr. G. Archey, Mr. B. C. Aston, Dr. W. R. B. Oliver; representing Auckland Institute, Mr. A. T. Pycroft; representing Wellington Branch, Dr. L. I. Grange, Dr. L. R. Richardson; representing Canterbury Branch, Dr. R. A. Falla, Dr. O. H. Frankel; representing Otago Branch, Dr. F. J. Turner; representing Nelson Institute, Dr. D. Miller; representing Southland Branch, Professor W. P. Evans; representing Hawke's Bay Branch, Mr. G. V. Hudson; Co-opted Member, Dr. J. Marwick; the Honorary Treasurer, Mr. S. Cory-Wright.

Apologies for Absence: Apologies were received from His Excellency the Governor-General, the Hon. Minister of Scientific and Industrial Research, Lieut.-Colonel E. Marsden (at present in Great Britain), Professor H. W. Segar, and Dr. C. M. Focken (both on account of railway restrictions).

New Members: The President extended a welcome to Dr. Richardson, who took his seat for the first time as a representative of the Wellington Branch, and to Mr. S. Cory-Wright, who had accepted the appointment of Honorary Treasurer in succession to Mr. M. A. Eliott, whose resignation on account of ill health came before the last annual meeting.

Presidential Address: The President announced the death of three distinguished Honorary Members of the Society—Sir Albert Seward, Sir Edwin Butler, and Mr. F. Chapman.

Dr. Allan then read his Presidential Address, the title of which was "Seventy-five Years of '*Transactions*'."

At the conclusion of the address Dr. Marshall thanked the President, and on his motion, seconded by Dr. Archey, it was resolved that the President be asked to allow his address to be printed in the *Transactions.*

Notices of Motion: Two Notices of Motion were handed in for consideration later in the meeting.

Hon. Treasurer's Report: Mr. Cory-Wright presented his annual report and statements of account. On the motion of Mr. Aston, seconded by Mr. Hudson, the balance sheet and accounts were adopted.

REPORT OF HONORARY TREASURER.

The finances of the Society continue to prosper, very much on the same lines as in recent years. The surplus of assets over liabilities on general account stands at £859 0s 3d, thus showing an increase of assets of £166 11s 7d on last year. As previously, this does not take into account the value of the Society's property in the Library, stock, and furniture, which is mentioned in a separate statement and is insured for £5540.

Printing Costs.—Although there was an increase in the price of blocks the amount for printing shows a slight decrease (£27) on last year's figure. The Rule that authors be required to meet the excess amount of papers costing over £20 to print was applied, and £11 was received from authors. In addition, Victoria University College paid the full cost of a special paper contributed by some members of its staff. Thus the actual cost to the Society this year for printing was £507 8s 10d.

The Trust Accounts continue to grow, being about £90 higher than last year, and there is in the Hutton Fund Revenue Account an amount of £320 available for research.

The Endowment Fund now stands at £2,207 12s 4d, an increase of £92 7s 8d. £150 Inscribed Stock belonging to this fund matured during the year and it was reinvested on the 6th March in the new 3% Conversion Loan maturing 15/4/1960-63.

I would pay a tribute to the excellent services of our Secretary in the keeping of the accounts.

MEMBER BODIES.

The following summarises the Income and Expenditure Accounts of the Member Bodies:—

	Members	Receipts	Expenditure	Levy		Rule 3
		£	£	£	s.	
Auckland Institute ..	565	12,287	12,571	47	7	Library, Museum, and Levy
Wellington Branch ..	229	202	212	45	15	Library, Levy
Canterbury Branch ..	133	192	200	28	19	Library, Levy
Otago Branch ..	150	255	197	48	10	Levy
Hawke's Bay Branch	54	24	30	2	2	Library, Levy
Nelson Institute / Southland Branch	Reports not yet to hand.					

April 26, 1944. (Signed) S. CORY WRIGHT, *Honorary Treasurer*.

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31st MARCH, 1944.

Receipts.	£	s.	d.
Balance at 31st March, 1943	867	13	7
Government Annual Grant	750	0	0
Levy on Volume 72	191	19	0
Sales of Publications	77	1	8
Travelling Expenses: Member Bodies' Share	20	10	5
Authors' Excess Cost of Papers	20	13	0
Favourable Exchange	1	3	11
Dominion Museum: Half Share Carter Library Ins. Prem.	0	17	0
Interest on P.O. Savings Bank Account	15	16	8
Endowment Fund, Interest	78	1	0
Hector Memorial Fund, Interest	52	13	9
Hutton Memorial Fund, Interest	70	6	3
Carter Library Legacy, Interest	6	10	0
Cockayne Memorial Fund, Interest	11	16	5
T. K. Sidey Summer-time Fund, Interest	23	17	8
Hamilton Memorial Fund, Interest	2	10	3
Plant Diseases Trust, Interest	17	19	4
Adjustments between Trust Accounts and Bank of N.Z.	89	1	4
	£2,298	11	3

Payments.	£	s.	d.
Printers—Vol. 72 (4), 73 (1, 2, 3)	528	1	10
Salary	325	0	0
Stationery	10	1	9
Charges (Insurance, Telephone, Audit, etc.)	14	0	1
Petty Cash (Secretary and Hon. Editor)	11	18	3
Binding Periodicals	18	0	0
Travelling Expenses	30	5	3
Hector Prize and Engraving Medal	50	14	3
Hamilton Prize	5	0	0
Trust Funds Audit	1	9	6
Hutton Grants	5	5	0
Sidey Summer-time Fund: Advt. re Award	2	10	0
Hutton Fund: Trav. Exs. Award Committee	5	5	0
Hector Fund: Trav. Exs. Award Committee	6	4	6
Trust Funds paid direct to Accounts	165	9	8
Adjustments between Bank N.Z. and Trust Accounts	10	5	6
Balance as Under	1109	0	8
	£2,298	11	3

Bank of New Zealand	206 3 1	
Less Unpresented Cheques	16 5 10	
		189 17 3
Post Office Savings Bank		912 11 8
Petty Cash in Hand		6 11 9
		£1,109 0 8

STATEMENT OF ASSETS AND LIABILITIES AT 31st MARCH, 1944.

Liabilities.	£	s.	d.
Hector Memorial Fund Capital Account	1,184	18	1
Hector Memorial Fund Revenue Account	77	12	8
Hutton Memorial Fund Capital Account	1,506	8	6
Hutton Memorial Fund Revenue Account	320	8	1
Sidey Summer-time Fund Capital Account	534	8	8
Sidey Summer-time Fund Revenue Account	130	14	6
Cockayne Memorial Fund Capital Account	249	12	0
Cockayne Memorial Fund Revenue Account	77	18	4
Hamilton Memorial Fund Capital Account	72	15	0
Hamilton Memorial Fund Revenue Account	1	17	1
Carter Library Legacy Capital Account	162	19	0
Carter Library Legacy Revenue Account	2	3	7
Plant Diseases Trust Capital Account	542	13	5
Plant Diseases Trust Revenue Account	17	14	10
Endowment Fund Capital Account	2,014	2	5
Endowment Fund Revenue Account	193	9	11
Library Fund	28	6	4
Research Grant Fund	122	0	6
Annual Subscriptions Trans. in advance	3	0	0
Balance of Assets over Liabilities	859	0	3
	£8,102	3	2

Assets.	£	s.	d.
Hector Memorial Fund, Inscribed Stock (Face Value £1250)	1,184	18	1
Hector Memorial Fund, P.O.S.B. Account	77	12	8
Hutton Memorial Fund, Inscribed Stock (Face Value £1,570)	1,506	8	6
Hutton Memorial Fund, P.O.S.B. Account	320	8	1
Sidey Summer-time Fund, Inscribed Stock (Face Value £510)	500	2	6
Sidey Summer-time Fund, P.O.S.B. Account	165	0	8
Cockayne Memorial Fund, Inscribed Stock (Face Value £260)	249	12	0
Cockayne Memorial Fund, P.O.S.B. Account	77	18	4
Hamilton Memorial Fund, Inscribed Stock (Face Value £60)	60	0	0
Hamilton Memorial Fund, P.O.S.B. Account	14	12	1
Carter Library Fund, Inscribed Stock (Face Value £160)	162	19	0
Carter Library Fund. P.O.S.B. Account	2	3	7
Plant Diseases Fund, Inscribed Stock (Face Value £500)	500	0	0
Plant Diseases Fund P.O.S.B. Account	60	8	3
Endowment Fund, Inscribed Stock (Face Value £2,045)	2,014	2	5
Endowment Fund, P.O.S.B. Part General Account	193	9	11
Post Office Savings Bank	719	1	9
Bank of New Zealand	189	17	3
Petty Cash in Hand	6	11	9
Outstanding Accounts (Wheldon and Wesley, £73 14s 1d; Sundry, £23 2s 3d)	96	16	4
	£8,102	3	2

April 26, 1944. S. CORY-WRIGHT, *Hon. Treasurer.*

The Audit Office having examined the balance sheet and accompanying accounts, required by law to be audited, hereby certifies them to be correct.

CYRIL COLLINS, *Controller and Auditor-General.*

PROPERTY ASSETS—ESTIMATED AND INSURED VALUE.

	Estimated Value. £	s.	d.	Insured Value. £	s.	d.
Library and Stack Room, Victoria University College	11,592	12	0	4,500	0	0
Furniture				40	0	0
Stock in Store Room, Parliament Bldgs.				500	0	0
Carter Library, Dominion Museum (jointly owned with Dominion Museum)				500	0	0

REVENUE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1944.

Expenditure.	£	s.	d.
To Printing *Transactions*, Vol. 72 (4), 73 (1, 2, 3)	528	1	10
,, Stationery	10	1	9
,, Salary	325	0	0
,, Petty Cash (Secretary, Hon. Editor)	11	18	3
,, Travelling Expenses	9	14	10
,, Charges (Insurance, Telephone, Audit, Bank)	11	19	2
,, Balance	859	0	3
	£1,755	16	1

Income.	£	s.	d.
By Balance, 31/3/43	692	8	8
,, Annual Grant	750	0	0
,, Levy	191	4	0
,, Sales and Authors' Excess Costs	102	0	11
,, Trust Funds Administration Expenses	5	2	6
,, Publication Expenses from Hutton Grant	15	0	0
	£1,755	16	1
By Balance	£859	0	3

Trust Accounts for the Year Ended 31st March, 1944.

Hector Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Hector Prize (Dr Briggs)	50	0	0	By Capital Invested ..	1,184	18	1
„ Exchange on cheque ..	0	1	3	„ Bal. Revenue 31/3/43	83	2	8
„ Engraving Medal ..	0	13	0	„ Interest	52	13	9
„ Trav. Exs. Award Committee	6	4	6				
„ Administration Exs.	1	5	0				
„ Balance	1,262	10	9				
	£1,320	14	6		£1,320	14	6
				By Balance	£1,262	10	9

Hutton Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Hutton Grants	20	5	0	By Capital Invested ..	1,506	8	6
„ Trav. Exs. Award Committee	5	5	0	„ Bal. Rev. A/c 31/3/43	276	16	10
„ Administration Exs.	1	5	0	„ Interest	70	6	3
„ Balance	1,826	16	7				
	£1,853	11	7		£1,853	11	7
				By Balance	£1,826	16	7

T. K. Sidey Summer-time Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Exs. ..	1	5	0	By Capital Invested and in P.O.S. Bank ..	532	0	11
„ Advt. re Award ..	2	10	0	„ Bal. Rev. A/c 31/3/43	112	10	7
„ Balance	665	3	2	„ Interest to Revenue	21	0	11
				„ Interest to Capital	2	7	0
	£668	18	2		£668	18	2
				By Balance Cap. A/c ..	£534	8	8
				„ Balance Rev. A/c ..	£130	14	6

Cockayne Memorial Fund.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Administration Exs.	0	2	6	By Capital Invested ..	249	12	0
„ Balance	327	10	4	„ Bal. Rev. A/c 31/3/43	66	4	5
				„ Interest	11	16	5
	£327	12	10		£327	12	10
				By Balance	£327	10	4

Hamilton Memorial Fund.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Prize (C. A. Fleming)	5	0	0	By Capital Invested and in P.O.S. Bank ..	71	9	10
„ Administration Exs.	0	5	0	„ Bal. Rev. A/c 31/3/43	5	17	0
„ Balance	74	12	1	„ Half Interest to Rev.	1	5	1
				„ Half Interest to Cap.	1	5	2
	£79	17	1		£79	17	1
				By Balance	£74	12	1

Carter Library Legacy.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Bal. Rev. A/c 31/3/43	3	11	5	By Capital Invested ..	162	19	0
„ Administration Exs.	0	15	0	„ Interest	6	10	0
„ Balance	165	2	7				
	£169	9	0		£169	9	0
				By Balance	£165	2	7

Plant Diseases Trust.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Administration Exs.	0	4	6	By Capital Invested and in P.O.S. Bank ..	542	13	5
„ Balance	560	8	3	„ Interest	17	19	4
	£560	12	9		£560	12	9
				By Balance	£560	8	3

Endowment Fund.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Administration Exs.	1	10	0	By Capital Invested ..	2,014	2	5
„ Balance	2,207	12	4	„ Bal. Rev. A/c 31/3/43	101	2	3
				„ Interest	78	1	0
				„ Interest P.O.S. Bank General Account ..	15	16	8
	£2,209	2	4		£2,209	2	4
				By Balance	£2,207	12	4

Hector Award: The President read the following report of the Hector Award Committee:—

"The Committee, consisting of Dr. P. Buck, Dr. H. D. Skinner, and myself, appointed at the last annual meeting to make a recommendation for the award of the Hector Medal in Ethnology, have carefully considered the work of all ethnologists known to them who qualify under the conditions of the award, and are unanimous in recommending that the Medal and Prize for 1944 be awarded to Mr. Johannes C. Andersen, M.B.E.

"(Signed) W. R. B. Oliver."

On the motion of Dr. Oliver, seconded by Dr. Grange, the report was adopted.

Amount of Hector Prize: It was agreed that the prize be £50 as usual.

Hutton Award: The President read the following report of the Hutton Award Committee:—

"The Hutton Award Committee, consisting of Professor J. A. Bartrum, Dr. D. Miller, and the Rev. Dr. J. E. Holloway (Convener) met at Christchurch on October 22 to consider the award of the Hutton Medal for 1944.

"The Committee unanimously agreed to recommend that the award be made to Professor W. N. Benson, D.Sc., F.R.S., for his research work on New Zealand geology.

"Dr. Benson's researches have covered practically the whole field of New Zealand geology with important original work on petrology, structural and petrographic studies in Otago, geomorphology, and research (with collaborators) on New Zealand graptolites. Certain of his papers, published either before or after his arrival in New Zealand, have a world-wide repute.

"He has had a notable inspirational influence on New Zealand research geologists who have passed through his hands.

"(Signed) JOHN E. HOLLOWAY."

On the motion of Dr. Marshall, seconded by Dr. Allan, the Committee's report was adopted.

T. K. Sidey Summer-time Award: Dr. Allan reported that Dr. Marsden, a member of the Award Committee had been absent from New Zealand, leaving Dr. C. E. Hercus and himself to recommend an award. Only two applications for the award had been received, and neither of these was considered worthy of the Medal and Prize. Later in the day Dr. Hercus wrote confirming these views.

On the motion of Professor Evans, seconded by Mr. Pycroft, it was resolved that the T. K. Sidey Summer-time Award be postponed until next annual meeting.

Dr. Marshall stated that there appeared to be some difficulty in interpreting the terms of the award. Dr. Turner agreed that it would be desirable to have the terms of the Deed of Trust amended so as to widen the scope of the award.

Fellowship: The Fellowship Selection Committee recommended that Mrs. Lucy May Smith (née Cranwell) and Mr. F. T. Seelye be elected Fellows of the Royal Society of New Zealand. On the motion of Dr. Archey, seconded by Dr. Falla, the recommendation was adopted.

Qualifications of Honorary Membership: In accordance with a resolution of last annual meeting the views of Member Bodies as to whether special weight should be attached to nominees for Honorary Membership whose scientific work was directly connected with New Zealand were ascertained.

The majority of the Member Bodies did not view favourably any such restriction in the choice of Honorary Members, and no further action was taken in the matter.

Election of Honorary Members: An election for two Honorary Members resulted in Dr. Lelland O. Howard and Professor Robert A. Millikan being elected.

Vacancies in Honorary Membership: Three vacancies in the Honorary Membership caused by the deaths of Sir Albert Seward, Sir Edwin Butler, and Mr. F. Chapman were declared, and on the motion of Dr. Grange, seconded by Mr. Pycroft, it was resolved that the three vacancies be filled at the next annual meeting.

Member Bodies' Reports and Balance Sheets: The following reports and balance sheets were laid on the table:—

Auckland Institute for the year ended 31st March, 1943.
Wellington Branch for the year ended 30th September, 1943.
Canterbury Branch for the year ended 31st October, 1943.
Otago Branch for the year ended 31st October, 1943.
Hawke's Bay Branch for the year ended 31st December, 1943.
Southland Branch for the year ended 31st March, 1944.
Nelson Institute for the year ended 31st December, 1943.

Report of the Standing Committee: In moving the adoption of the report of the Standing Committee the President referred to the attendance at the Standing Committee meetings and extended an invitation to any members of the Council visiting Wellington to attend any meetings being held during their visit. He also thanked Mr. R. L. Andrew for his assistance during the period during which he represented the Wellington Branch. Dr. Marshall seconded the motion, and the report was adopted without further discussion.

REPORT OF THE STANDING COMMITTEE FOR THE YEAR ENDED 31ST MARCH, 1944.

Meetings: Seven meetings of the Standing Committee have been held during the year, the attendance being as follows:—Dr. H. H. Allan, President, Wellington, 7; Dr. P. Marshall, Vice-President, Wellington, 7; Mr. R. L. Andrew, Wellington, 3; Dr. G. Archey, Auckland, 1; Mr. B. C. Aston, Wellington, 7; Professor W. P. Evans, Wellington, 7; Dr. R. A. Falla, Christchurch, 1; Dr. L. I. Grange, Wellington, 5; Mr. G. V. Hudson, Wellington, 7; Dr. E. Marsden, Wellington, 2 (Dr. Marsden has been absent from the Dominion on work of national importance); Dr. J. Marwick, Wellington, 5; Dr. W. R. B. Oliver, Wellington, 7.

Council: At last annual meeting Dr. J. Marwick was appointed co-opted member. Professor E. R. Hudson, Government representative, resigned his seat on the Council owing to his inability to attend meetings of the Society, and this vacancy was filled by the Government by the appointment of Dr. G. Archey.

Mr. R. L. Andrew succeeded Dr. Allan as representative of the Wellington Branch, and he has been succeeded by Dr. L. R. Richardson.

Other personnel on the Council remain the same as last year.

Honorary Treasurer: The last annual meeting authorised the Standing Committee to make the appointment of Honorary Treasurer to succeed Mr. M. A. Eliott, who had resigned because of ill-health. At a meeting on the 3rd June it was resolved that Major J. R. Kirk be asked to accept the position. Major Kirk agreed, but, unfortunately, on the day on which he was to be formally appointed, his sudden death was announced.

Mr. S. Cory-Wright, of Messrs Cory-Wright and Salmon, engineers, of Wellington, was then approached, and he agreed to accept the position.

Mr. Cory-Wright assumed the duties of Hon. Treasurer and was welcomed by the President at a meeting of the Standing Committee on the 15th December, 1943, and he has since attended meetings of the Committee. His advice on financial matters will be of great value to the Standing Committee and the Society.

Publications: Printing costs have been again increased, this time by the block-makers. Part 1 of Volume 73 contained a coloured plate on Collembola. Some complaints on the printing of some of the plates in the last volume were referred to the printers, and it is hoped that there will be an improvement in this direction. Adverse criticism regarding the quality of the paper used in the *Transactions* was met by the printers stating that they were unable to obtain

further supplies of the English paper previously used and they were endeavouring to have an improvement effected in the quality of the Canadian paper, the only paper now available.

Library: Binding—Owing to labour shortage and increased priority work the binder has not been able to complete more than 40 volumes during the year. It is hoped that a further supply will soon be ready.

In addition to the use of the Library by the staff and honours' students of Victoria University College and members of the Society many volumes have been posted to members in other towns and these postal facilities are appreciated by those who have not direct access to the Library.

Exchanges: A further curtailment of incoming exchanges was made during the year by an extension of the censorship regulations to neutral countries. This also affected the transmission of the *Transactions*, and the volumes are being placed aside to be forwarded when the ban is removed.

The exchanges which are still permitted continue to come with more or less regularity and there are comparatively few losses caused by enemy action. Many requests for second copies of Volume 72 Part 2 were received, and it was feared that all copies for overseas institutions and orders must have been lost. Some time later, however, it was learned that the Part had reached its destination after Part 3 had been received. It had apparently been delayed in transit.

The Royal Society of Canada was added to the Exchange list to receive the Society's *Transactions*. Publications from the Royal Society of Canada had been coming to the Library for many years, but there had not been reciprocity in sending publications.

At the suggestion of Dr. Archey that an endeavour be made to obtain sufficient sets of the *Transactions* to replace those lost in war devastated libraries on our exchange list Member Bodies were asked to supply as many spare copies as possible, particularly of the more rare early numbers. So far the only Member Body to respond has been the Otago Branch which forwarded volumes for this purpose. Dr. Archey has also stated that if necessary his own set will be available for the above purpose. Owing to the lack of space in the Society's rooms it would be a convenience if Member Bodies in the meantime would store spare volumes contributed by members and merely forward a list to the Secretary.

Member Bodies: The following reports and balance sheets have been received:—

Auckland Institute for the year ended 31st March, 1943.
Wellington Branch for the year ended 30th September, 1943.
Canterbury Branch for the year ended 31st October, 1943.
Otago Branch for the year ended 31st October, 1943.
Hawke's Bay Branch for the year ended 31st December, 1943.

The above reports and balance sheets have been reported on by the Honorary Treasurer in his annual report.

Fellowship: Eleven nominations for the two vacancies in the 1944 Fellowship were received from Member Bodies and were submitted to the Fellows for selection. Their selection was placed before the Fellowship Selection Committee on the 14th March, 1944, and its recommendation will be considered at the annual meeting in May.

Honorary Membership: The following resolution, passed at the annual meeting last year, was forwarded to Member Bodies for consideration:—

> "That this Council, after obtaining the opinions of Member Bodies, consider the desirability of attaching special weight to nominees for honorary membership of the Society whose scientific work is directly connected with New Zealand."

Wellington Branch, Canterbury Branch, and Nelson Philosophical Society did not favour any such consideration being shown in the choice of honorary Members. The Otago and Southland Branches considered such steps desirable. No replies were received from the other Member Bodies. The matter will come before the annual meeting for further consideration.

Six nominations for the two vacancies in the Honorary Membership have been received from Member Bodies and an election will take place at the annual meeting in May.

Hector Award: At a meeting of the Auckland Institute held on the 16th August, Dr. H. H. Allan, President of the Society, presented the Hector Medal and Prize to Dr. L. H. Briggs for his researches in chemistry.

Hamilton Prize: At the same meeting Dr. Allan presented the Hamilton Prize to Mr. C. A. Fleming.

Hutton Grants: An application from Mr. L. E. Richdale for a grant of £20 to enable him to carry on ornithological research at Stewart Island was recommended for approval to the annual meeting.

An application from the Southland Branch for £40 to assist it in the erection of a hut on Whero Island was referred back for further particulars.

Whero Island: At the instigation of the Otago and Southland Branches it was decided to approach the Lands and Survey Department with a request that Whero Island be made an observation station for the study of bird life. On the 28th October advice was received from the Department that it was prepared to grant the Southland Branch authority to erect a hut for observational purposes and to occupy it for a period of five years on the understanding that Government officials or any persons authorised by the Department be allowed to visit the Island at any time.

T. K. Sidey Summer-time Award: Notice that an award of the T. K. Sidey Summer-time Medal and Prize would be made at the annual meeting in May, 1944, was advertised in all the principal newspapers in the Dominion on the 30th July, 1943. A notice was also sent to all the scientific societies whose names were on the list approved at the last annual meeting.

The Award Committee will make its report to the annual meeting.

Loder Cup: At a meeting of the Standing Committee held on 15th December it was decided to nominate Mr. W. H. Field for the Loder Cup, 1943.

Advice was received from the Loder Cup Committee on the 14th February, that the Loder Cup had been awarded to the Mr. J. Speden, of Gore.

Science Teaching in Schools: A suggestion was made to the Committee set up by the Minister of Education to report on the post-Primary school curriculum that it meet the Standing Committee of the Royal Society to discuss the proposals in regard to science teaching.

The Committee replied that its work was completed and no good object would be achieved by such a conference. The report, when published, would be submitted to those interested and any recommendations would then be considered by the Committee.

The published report was placed before the Standing Committee on the 22nd February and referred to a sub-committee consisting of Dr. Allan, Dr. Oliver, Dr. Marwick and Dr. Grange for consideration and report to a later meeting.

Research Grant: At a meeting of the Standing Committee held on the 3rd June an application from Dr. L. H. Briggs for a research grant of £25 for the continuation of an investigation of the essential oils of plants was granted.

Theses: It was pointed out by the Wellington Branch that it would be an advantage to have students' theses preserved and listed by the University Colleges so that they might be available for reference. The matter was referred to Professor Evans, who subsequently reported that the University Colleges kept fairly good lists of theses, and it had been decided to publish each year in the *N.Z. University Calendar* a list of all theses presented, and there was a possibility that the lists would be made retrospective to 1940. Separates of the lists could be supplied to interested organisations. College libraries will house the theses recorded in the lists.

Physics Course: In reply to a resolution passed at the last annual meeting urging the Director of Education to offer every encouragement to students to study physical science and mathematics (including engineering), the Director stated that the Department had realised the importance of such study and had already taken steps to direct the minds of intending University students to the above courses.

Pacific Science Congress Reports: Through some misunderstanding between the Committee of the Sixth Pacific Science Congress and the University of California Press the *Reports of the Sixth Pacific Science Congress* were not sent to

the Society which is the representative body in New Zealand. After much correspondence the Reports (six volumes) have now been received and are in the Royal Society's Library.

Memorials to Past Scientists: The Wellington Branch sent to the Standing Committee for consideration certain recommendations in regard to commemorating the life and work of eminent New Zealand scientists. The following recommendations were approved:—

1. That plaques to commemorate eminent New Zealand scientists be erected in places associated with their work.
2. That educational and research buildings be named after such men.
3. That a suggestion be made to museums to stage suitable exhibits to commemorate the work of such scientists.
4. That a list of the past most eminent New Zealand scientists be drawn up by the Standing Committee.

The following list was subsequently drawn up:—"Rutherford, Mellor, Hector, Skey, Hutton, McKay, Haast, Cockayne, Best, and J. M. McLaren."

Hon. Editor's Report: On the motion of Dr. Marwick, seconded by Dr. Allan, the report of the Honorary Editor was adopted. Dr. Marwick was warmly thanked for his work as Honorary Editor during the year.

Report of Honorary Editor.

During the year ended 31st March, 1944, the four parts of Volume 73, *Transactions R.S.N.Z.* comprising 442 pages and 52 plates (one in colour) have been printed, compared with 439 pages and 44 plates of the previous volume. Volume 73 is made up as follows:—

	No. of Papers.	Pages.	Plates.	Figures.
Geophysics ..	1	4	—	—
Hydrography ..	1	12	—	6
Geology	7	82	10	19
Palaeontology ..	3	44	10	—
Botany	5	84	9	—
Zoology	16	145	19	3
Proceedings ..	—	44	—	—
Obituaries ..	4	11	4	—
Appendix ..	—	8	—	—
Index	—	8	—	—
	37	442	52	28

The following manuscripts have been handled during the year:—

Manuscripts printed in Volume 73	37
In press in Part 1, Vol. 74	5
Returned for revision to authors and not yet returned ..	1
In hand	6
Total	49

The average time between the final receipt of papers and their publication has been about six months, the longest, nine months, and the shortest, three months.

Once again the Editor has to thank the Associate Editor, Dr. C. O. Hutton, for his valuable and ever ready help.

J. Marwick, *Honorary Editor.*

Hon. Librarian's Report: On the motion of Professor Evans, seconded by Dr. Allan, the report of the Honorary Librarian was adopted.

Report of Honorary Librarian.

As there have been no applications from institutions to be placed on the Society's Exchange List it has not been necessary to call the Library Committee together during the past year.

The Library continues to be of service to members and to the Victoria University College staff and honours' students and its facilities have also been appreciated by research workers in other centres. To a certain extent, also, it is serving a direct purpose in the war effort by the use made of it during the year by scientists engaged in work of national and military importance and by U.S.A. medical service men who wished to acquire the latest knowledge in regard to the mosquito and its bearing on malaria in the Pacific Islands.

The amount of binding completed during the year has been restricted because of the volume of other work which the binder has in hand.

W. P. Evans, *Honorary Librarian.*

Research Grantees: On the motion of Dr. Archey, seconded by Professor Evans, the reports of the research grantees were adopted.

Reports of Research Grantees.

Government Research Grants.

Professor B. J. Marples, who received a grant of £20 in 1938 for research on the Little Owl, reported on 21st April, 1944, that owing to war conditions he has not yet been able to undertake the biological survey of Green Island, for which the balance of his grant, namely £5, was allocated. He asks that the grant may be held over until the times are more opportune.

Dr. L. H. Briggs, who on the 3rd June, 1943, was granted £25 for a continuation of an investigation of essential oils of trees and plants endemic to New Zealand reported on the 2nd May, 1944, that the special fractionating apparatus being purchased under this grant has not yet been received and the grant has as yet not been applied for.

Hutton Research Grants.

Dr. F. J. Turner, who was granted £50 in 1941 and 1942 for research on metamorphic rocks, reported on the 21st April that £15 of the grant was used, by permission, for paying the excess cost of the publication of a paper on "Preferred Orientation of Olivine." The sum of £9 (approximately) was expended upon cutting oriented sections from rocks collected at Manapouri and near Glenorchy. Expenditure of £16 had been previously reported, leaving an unexpended balance of £10 2s 6d, which he would like held over for further work next year. During the year he has done no further laboratory work, but hopes to resume the research early next year. The petrofabric investigation of the Glenorchy sections was part of a research carried out by Mr J. J. Reed under his direction, and the results will be published shortly in the American Journal *Economic Geology.*

To date Dr Turner has published two papers embodying the results of the research and he has in hand material for at least one more paper.

Dr. R. A. Falla and Mr. A. W. B. Powell were in 1934 granted £40 for a research on the Molluscan and Bird Fauna of the Sub Antarctic Islands. Since that time it has not been possible for grantees to undertake the investigation, but Dr. Falla has now reported that the grant has been expended.

The field work was done with the permission and assistance of the Royal New Zealand Navy, and Navy Office has made it conditional that no description shall be published nor information divulged during the war. For this reason Dr. Falla states that he is unable to supply more detail of the research or give details of the expenditure at the present time.

Mr L. E. Richdale, who in 1942 was granted £40 for ornithological research, reported on the 30th April, 1944, that work on Whero Island has continued, and there are 500 burrows involving 5 species of petrels under observation.

With the erection of a hut he has been able to re-mark these burrows with totara and hardwood pegs, each carrying a numbered aluminium tag. This will secure permanency and allow him to carry out research on aspects of ornithology which require many years.

As Mr Richdale need not now spend so much time on Whero he intends to extend operations to islands all round Stewart Island. The hut will greatly assist these projects.

Of the six papers mentioned in last year's report, four have been published while the remaining two should appear this year. Both are in the hands of editors.

Tongariro National Park: Dr. Marshall, in moving the adoption of his report as representative of the Society on the Tongariro National Park Board, stated in reply to a question that it was difficult to estimate just what area of the Park was covered by heather as it was so scattered. The heather did not grow on bare ground but chiefly where the native vegetation had previously been burnt off. The heather had been planted, without the authority of the Board, by the then warden of the Park, with the intention of liberating grouse for sporting purposes.

Dr. Archey suggested that the possibility of eradicating the heather by mechanical means such as bull-dozers might be explored.

The report was adopted.

Tongariro National Park Board.

Report of Representative.

I visited the Tongariro National Park on 27th January, 1944, in company with Mr. Lawrey, acting secretary of the Board, and Mr. Boulton, field inspector of the Lands and Survey Department.

The area on which heather (*Calluna vulgaris*) has been growing in the Park for about 20 years is considerable. Its extent, however, is not definitely known; it is not exactly certain where it was originally sown by the late Mr. Cullen. Consequently the question as to the rate the plant spreads in this area cannot be definitely answered.

At the present time it is growing most thickly at the point where the road to the Chateau leaves the Main Highway. In this locality it is growing on both sides of each of the roads. It does not extend far from the road on the north side of the Main Highway, but on the south side, it has an irregular border extending at times to a distance of one mile from the road.

On the sides of the road to the Chateau it grows thickly as far as the tongue of bush through which the road passes, but was not seen on the south side of that point. Although mainly marginal to the road it does not grow on the bare soil exposed on the roadside. Near the Chateau road the heather on the sides of the Main Highway is almost continuous for some distance back from the highway, but it gradually decreases in width until it becomes purely marginal and patchy, and was not seen after passing 15 miles eastward from the Junction.

It was the practice of Mr Cullen, as stated to the writer, to burn off the native vegetation and sow the heather seed on the burnt surface for the seed did not strike when scattered amongst the growing native vegetation. It is not possible to say now where the native vegetation was burnt, but remains of burnt scrub can be seen in many places where the heather is now growing. No heather plants can be seen on the bare ground exposed four years ago when the road to the Chateau was re-aligned.

It is probable that Mr. Cullen sowed the heather seed by the roadside. He had a consignment of 40lb of heather seed.

Close inspection of the vegetation opposite Roderick Gray's whare, a locality which has been undisturbebd for many years and where the ground is wet, shows that the heather has old, straggly stems 3 feet high. The ground is carpeted with a thick growth of native plants—*Coprosma, Dracophyllum, Lycopodium, Gleichenia, Pimelia*—close growing small plants. Very little young heather could be seen amongst the native plants. On drier ground the heather grows as rounded bushes about 2 feet high and 2½ feet in diameter. These seem to remain separated. The plants do not grow close together nor could young plants be seen between them. In some places, however, where there was some native vegetation mixed with heather, there were numerous young plants.

If heather seed is distributed by wind its spread must be very slow,

Isolated plants are found outside the National Park on the west side of the railway line. This ground has probably been repeatedly burnt.

I am inclined to think that if the native vegetation is left undisturbed the heather will not spread to any material extent and on the wetter ground there will be no spread but a gradual decrease.

A plant which spreads readily on this land is the European broom. At the present time this plant is found by the roadside in many places, especially close to the entrance to the Chateau road. However, it does not cover much ground, and it could probably be successfully dealt with now. The Tongariro National Park Board will take the matter in hand this year.

On this ground a new growth of native plants develops very slowly on a bare surface. The bare ground exposed by the road re-alignment four years ago remains uncovered. It has always been said that in this area a track once bared remains permanently without a plant covering.

In a report of the Tongariro National Park Board for 1927 the following statement is made: "It must be clearly understood that the bulk of the seed was planted many years before the present board was established in 1922." In the report for 1926 it is stated: "The Board being of the opinion that it is impossible to eradicate the heather save at a cost beyond the means of the Board resolves that no further heather seed be planted and that steps be taken to prevent the further spreading of the heather."

6th April, 1944. P. MARSHALL.

Board of Trustees, National Art Gallery and Dominion Museum: The report presented was amended, and on the motion of Dr. Marshall was adopted.

NATIONAL ART GALLERY AND DOMINION MUSEUM BOARD OF TRUSTEES.

Report of Representatives.

Quarterly meetings have been held regularly. The greater part of the Museum has been occupied by the military authorities for two years. Until recently this portion of the building had been used by the Army, Navy, and Air Force. The Board has been advised that the building will now be occupied by the Air Force only. The Board is now inquiring whether the Lecture Room and the Royal Society's (Wellington Branch) room can be released. Steps have been taken to arrange for the renovation of the Carillon.

P. MARSHALL.
W. P. EVANS.

6th April, 1944.

Royal N.Z. Institute of Horticulture: On the motion of Dr. Oliver, seconded by Dr. Allan, the report was adopted.

ROYAL NEW ZEALAND INSTITUTE OF HORTICULTURE.

Report of Representative.

Owing to the war the National Flower Show was not held, but the annual meeting of the Institute took place in January last.

Two numbers of the Journal of the Institute have been issued during the year, including informative articles on Fuchsias and on Education in Horticulture.

The syllabus in Horticulture of the Christchurch Technical College was received at the May executive meeting. It was noted with satisfaction that practically all the lecturers are Institute members.

Examining Board's Report.—There were 19 candidates at the November, 1943, examinations. It has been decided by the Board that candidates' theses should be retained and that a library for them should be formed under definite rules. To date 244 diplomas and 175 certificates have been issued.

W. R. B. OLIVER.

Great Barrier Reef Committee: On the motion of Dr. Oliver, seconded by Mr. Pycroft, the report was adopted.

GREAT BARRIER REEF COMMITTEE.

Report of Representative.

A meeting of the Committee was held at Brisbane on 8th December, 1943. Other than routine business, discussion took place on the future activities of the Committee, in which connection a letter from Vice-admiral Sir John Edgell was read. The Chairman stated that oceanographical work in the Barrier Reef was after the war likely to be greater than before. More boring was also likely to be done after the war. Sir John Edgell discussed questions concerning detailed mapping of the Reef, especially by aerial photography and by sounding on the outer edges of the reefs in order to obtain profiles.

The financial statement shows a balance of £1,777 15s 7d, of which £1,300 is in bonds.

W. R. B. OLIVER.

Observatories' Committee: The report of the representatives on the Observatories' Committee was adopted.

OBSERVATORIES' COMMITTEE.

Report of Representatives.

The Observatories' Committee has again not met during the past year. Dr. Barnett, Director of Meteorological Services, paid a visit to Apia in August, 1943, and Mr. Sapsford, Acting Director of the Apia Observatory, visited New Zealand during September, 1943.

The quarterly reports from the Apia Observatory and from the Dominion Observatory have been regularly received and they indicate satisfactory progress.

D. C. H. FLORANCE.

Carter Observatory Board: The report of the representatives on the Carter Observatory Board was adopted.

CARTER OBSERVATORY BOARD.

Report of Representatives.

There were three meetings of the Board during the year. Mr. M. M. F. Luckie and Dr. C. E. Adams were re-elected Chairman and Deputy Chairman respectively. Mr. R. A. McIntosh was appointed as one of the Government representatives on the Board in place of the late Professor C. Coleridge Farr.

Lieutenant-Colonel Stratton, Professor of Astrophysics at Cambridge University, during a short visit to Wellington, gave a lecture on Novae at the Carter Observatory on the 8th September. He also attended a meeting of the Board on the 13th September, at which his advice was sought on the future programme of work of the Carter Observatory.

The Director, Mr. M. Geddes, and Mr. I. L. Thomsen are still absent on naval service. Miss K. Turner has continued to carry out essential clerical duties and has co-operated with the Defence Development Section of the Scientific and Industrial Research Departmemnt in the provision of information derived from sunspot and auroral observations.

The Lecture Room at the Observatory was again used by the Meteorological Office during two periods of about ten weeks, in connection with training courses for Meteorological Officers.

In the absence of the Director and Assistant it has not been possible to arrange any regular programme to sustain the interest of the public in the Carter Observatory. The Board is particularly grateful, therefore, to Professor Stratton for his address and to Mr. E. P. Norman, a member of the Board, who gave a well attended lecture in the Public Library Lecture Hall on 20th April, his subject being "The Story of the Giant Telescope."

The Observatory and equipment have been maintained in good order and the surroundings kept tidy by arrangement with the Reserves Department of the City Council.

M. A. F. BARNETT.
C. G. G. BERRY.

Hutton Grants: An application from Mr. L. E. Richdale for £20 for ornithological research at Stewart Island was approved.

An application for £40 from the Southland Branch towards the cost of erecting a hut on Whero Island for observational purposes in ornithological research was approved.

Hutton Award: The President read a letter from the Otago Branch asking the Council to reconsider its decision of the previous annual meeting that the Hutton Fund may not be used for publication purposes.

Dr. Turner moved and Dr. Grange seconded—" That this Council approves the principle of making grants from the Hutton Fund to defray cost of approved papers in botany, zoology, and geology which otherwise would be charged to authors provided that such action is first confirmed by written legal opinion."

A good deal of discussion on the interpretation of the terms of the award took place, and at the suggestion of Dr. Archey the mover and seconder of the motion agreed to delete the words " provided that such action is first confirmed by written legal opinion."

On being put to the meeting the motion was lost.

Lunch Adjournment: The lunch adjournment was taken at 12.45 p.m.

Roll Call: On resuming at 2.15 p.m., the roll call was taken as follows:—The President (Dr. Allan), the Vice-President (Dr. Marshall), Dr. Archey, Dr. Oliver, Mr. Pycroft, Dr. Grange, Dr. Richardson, Dr. Falla, Dr. Frankel, Dr. Turner, Mr. Hudson, Dr. Miller, Professor Evans, Dr. Marwick, all being present.

Publication Costs: Dr. Turner moved, Dr. Falla seconded— " That the rule restricting any one paper to £20 be rescinded.

Dr. Grange stated that the Wellington Branch supported the above motion if the Society's annual Government grant is increased to £1250. He moved an amendment, which was seconded by Dr. Richardson—" That the rule restricting any one paper to £20 be rescinded if the annual Government grant be restored to £1250."

On being put to the meeting the amendment was lost.

Dr. Turner's motion was then carried.

Science Teaching in Schools: Dr. Allan read the report of the Sub-committee consisting of Dr. Allan (convener), Dr. Oliver, Dr. Marwick, and Dr. Grange, which had been set up by the Standing Committee to consider the published report on the post-primary curriculum. A general discussion in which members expressed their views on the various points raised took place.

Finally, on the motion of Dr. Archey, seconded by Dr. Falla, it was resolved to ask the Sub-committee to add to its report an outline of " the more logical and ordered arrangement of the syllabus " that it recommends.

Education Conference: The President stated that the Minister of Education proposed to hold an Education Conference in August in Christchurch and had invited the Society to send a delegate and to express its opinions on the topics for discussion. On the motion of Dr. Archey, seconded by Dr. Marshall, it was resolved that the Society send a delegate to the Conference and that the matters dealt

with in the Minister's letter be referred to the Standing Committee. It was agreed, also, to leave the appointment of a delegate to the Standing Committee.

Annual Government Grant: A letter from the Wellington Branch regarding the need for an additional grant to the Society was read, and on the motion of Dr. Grange, seconded by Dr. Richardson, it was resolved that the Government be approached to restore the grant to £1250.

Wild Life Control: Dr. Oliver, Convener of the Wild Life Control Committee, reported progress in his committee, and stated that he hoped to be able to submit a full report in about three months.

Preservation of Miro: A letter from the Nelson Philosophical Society urging the protection and conservation of the Miro for the sake of the native pigeon was read. Dr. Miller stated that in the Nelson district, in connection with the hydro-electric scheme there, many Miro trees had been destroyed, and this gave rise to the above letter. In a discussion which followed the impracticability of preserving Miro trees which were scattered throughout the New Zealand forest was stressed. The matter was referred to the Wild Life Control Committee.

Endowment Fund: Professor Evans stated that the meeting had to consider the following resolution carried at the last annual meeting:—

> "That the Council at its next annual meeting decide for what object or objects the capital of the Endowment Fund may ultimately be used, and as soon as possible thereafter take the necessary steps to have a statement of these objects inserted in the Deed of Trust."

He stressed the danger of having any fund with no expressed object. According to the present Deed of Trust the capital of the fund could not be used for any purpose whatsoever.

A discussion on the origin of the fund took place, Mr. Hudson stating that he had always considered the fund had been intended to be utilised by the Society for building purposes.

Dr. Marshall moved, and Mr. Hudson seconded—"That the Endowment Fund be used for the erection or the purchase of a building to house the Royal Society's Library and for meetings."

The motion, on being put to the meeting, was lost.

After further discussion, Dr. Turner moved, Dr. Frankel seconded, and it was carried—"That the Endowment Fund be regarded as a fund for providing interest to be used for general revenue."

On the motion of Dr Allan, seconded by Dr. Marshall, it was resolved that the interest on the Endowment Fund for the year ended 31st March, 1944, be used for publication expenses.

Notice of Motion: On the motion of Mr. Hudson, seconded by Mr. Aston, it was resolved—"That some special efforts be made to encourage and enlist independent workers in all branches of natural science."

Secretary's Salary: It was resolved that the Secretary's salary be increased to £360 per annum.

Election of Officers: The folowing officers were elected:—

President: Dr. H. H. Allan (re-elected).
Vice-President: Dr. P. Marshall (re-elected).
Hon. Treasurer: Mr. S. Cory-Wright, M.C. (re-elected).
Hon. Editor: Dr. J. Marwick (re-elected).
Hon. Librarian: Professor W. P. Evans (re-elected).
Co-opted Member: Dr. J. Marwick (re-elected).
Managers Trust Accounts: Mr. Cory-Wright and Mr. B. C. Aston.
Representative Tongariro National Park Board: Dr. P. Marshall.
Representative Royal N.Z. Institute of Horticulture: Dr. W. R. B. Oliver.
Representative Great Barrier Reef Committee: Dr. W. R. B. Oliver.
Representative Observatories' Committee: Professors D. C. H. Florance and P. W. Burbidge.

Election of Committees: The following committees were elected:—

Hector Award Committee: Dr. J. Marwick (Convener), Dr. P. Marshall, and Professor J. A. Bartrum.
Library Committee: Professor W. P. Evans, Dr. H. H. Allan, and Professor C. A. Cotton.
Fellowship Selection Committee: Professor H. W. Segar, Dr. H. H. Allan, Dr. J. Marwick, Mr. B. C. Aston, Dr. R. A. Falla.
Wild Life Control Committee: Dr. W. R. B. Oliver (Convener), Dr. H. H. Allan, Dr. G. Archey, Mr. E. F. Stead, Dr. R. A. Falla, Mr. L. E. Richdale, and Rev. Dr. J. E. Holloway (re-elected).

Votes of Thanks: On the motion of the President, votes of thanks were accorded to Victoria University College, to the Press, to the S.I.R. Department for the use of its Council Room for Standing Committee meetings, and to the Secretary (Miss Wood).

A very cordial vote of thanks was passed to the President, Dr. Allan, for his work during the year and for his able chairmanship of the meeting.

Annual Meeting, 1945: It was decided to endeavour to arrange for a luncheon for members attending the 1945 annual meeting.

REPORTS OF MEMBER BODIES.

AUCKLAND INSTITUTE AND MUSEUM.

ANNUAL REPORT FOR 1943-44.

President: Mr. A. H. Johnstone, K.C., B.A., LL.B.
Director: Dr. Gilbert Archey, O.B.E., M.A., F.R.S.N.Z.

The year which has just closed has been one of restoration. Members will recollect that after the threat of invasion by the Japanese many of the more valuable books and collections had been removed from the Museum to places of greater safety.

It is a pleasure to report that the books have now been returned [illegible] library and the collections brought back to their accustomed places [illegible] Museum: the Maori houses which were partly dismantled have been [illegible] and re-painted, and the great war canoe has been uncovered and [illegible]

The Maori Court has again resumed its erstwhile pleasing appearance. The thanks of the Institute are due to Sir Frank Mappin, to Mrs. H. W. Shove, and to the Dilworth Trust Board for providing safe accommodation for the books and collections.

The public lectures, both evening and Sunday afternoon, have been revived in full and have received a full measure of public interest and support.

Staff: The Director, Lieut.-Colonel Gilbert Archey, was released from military service in July and returned at once to his duties at the Museum.

Mr. E. G. Turbott, Assistant Zoologist, proceeded on overseas military service in the same month.

The resignation of Mr. Edwin Leece, who was mechanic to the Museum since 1928, is recorded with regret.

Miss Lucy M. Cranwell, Botanist to the Museum, was married in September to Major S. Watson Smith, of the Army of the United States. In February she resigned in order to join her husband at Washington. By her resignation the Museum has lost the services of a distinguished scientist. Since her appointment in August, 1929, she has done excellent work in the care, extension, and developmemnt of the Cheeseman herbarium and in the general duties incidental to her office; in addition by her writings and lectures and by her interest in and enthusiasm for the annual Cheeseman Native Flower Show she did much to create public interest in the Museum and in botanical science. She was an assiduous collector of botanical specimens both in New Zealand and in other countries. During her vacations she undertook important research on the pollen grains found in swamp deposits; in New Zealand and in Sweden with Professor L. Von Post and in Hawaii with Professor C. Skottsberg. The Loder Cup "to encourage the production and cultivation of the incomparable flora of the Dominion" was awarded to her in 1937. Last year in collaboration with Captain Josiah E. Green, of the United States Marine Corps, and Mr. A. W. B. Powell, she prepared the booklet "Food Is Where you Find It" for the use of airmen and others who may be cast away on the Pacific Islands. The publication has needed four impressions (23,000 copies) for service requirements.

Membership: The membership of the Institute at the beginning of the year was 565. Of these we have lost 20 by death or resignation and 12 by deletion from the membership roll. Thirty-two ordinary and six life members were elected during the year. The roll, which includes five members of the United States Armed Forces, now stands at 571, of whom 174 are Life Members.

Obituary: The death of the following members is recorded with sincere regret:—Mrs. J. Kenderdine, Sir H. Horton, Dr. W. H. Horton, Dr. S. Stride, Hon. O. F. Nelson, Messrs. W. J. Bridson, J. Dempsey, H. R. Dix, R. L. Stewart, A. Suter and E. C. Turner.

Honours: Congratulations are extended to Dr. L. H. Briggs for the award of the Hector Medal by the Royal Society of New Zealand, and to Mr. C. A. Fleming on receiving the Hamilton Prize. The awards were conferred by Dr. H. H. Allan, President of the Royal Society, at a meeting at which Dr. Briggs delivered a public lecture on Hormones of Animals and Plants.

Council: The Council held six meetings during the year, all of which were well attended.

Finance: Revenue for the year showed an improvememnt through a satisfactory increase in members' subscriptions and the sale of publications, which are being freely purchased by United States servicemen; the return from investments is lower than in former years.

Expenditure on insurances has again been high, but will be less in the coming year; salaries and wages have also increased through the additional help required for returning the collections to the Museum. General expenses have been slightly lower and it has been possible to transfer £200 to the war contingencies reserve. The amount carried forward, £1,168, is the customary provision for April and May, which produce no revenue.

Public Activities: The Council has joined with the University College, Royal New Zealand Institute of Horticulture, Auckland Botanical Society, Alpine Sports Club and The Auckland Tramping Club in seeking representation of scientific and educational interests on the Auckland Centennial Memorial Park Board. It has also co-operated with the Society of Arts in urging the preservation of trees on State-housing subdivision districts. The representations made in this behalf were welcomed by the housing authorities. An appeal has been

made to members to donate back numbers of the "*Transactions of the Royal Society of New Zealand*" for replacement of sets destroyed during the war.

It has been decided to name the Native Natural History Hall the "Cheeseman Hall" in commemoration of the scientific work of the late Thomas Frederic Cheeseman.

There has been no lessening of public interest in the Museum and its activities since the outbreak of war. The frequent visits and inquiries of Allied Servicemen have taken a large but pleasant toll of the time of the staff. The important work among the children is being continually expanded and developed. Not only are more school children visiting the Museum and a wider variety of topics for classes being made available to them, but more specimens and information are going to schools far in the country. The only limit to this work is the physical impossibility of preparing and sending a larger number.

Gifts to the Museum: Captain G. A. Humphreys-Davies, Hon. Curator of Oriental Collections, has donated the whole of his valuable collection of Chinese pottery and porcelain, and has also secured for the Museum gifts of especially fine specimens from leading collectors abroad. He has also donated two valuable Chinese bronzes.

Mrs. Hemingway has given the late Mr W. H. Hemingway's extensive collections of rare and beautiful insects, both those displayed by Mr. Hemingway in the Museum and his large cabinet collection.

Mr. E. Earle Vaile has donated over 80 volumes and many pamphlets relating to discovery, exploration and Native life in New Zealand and the South Pacific.

A bequest of £500 by the late Mr. M. Harding was received during the year.

Owing to the generosity of Messrs. R. C. Horton, V. J. Larner, David Nathan, W. Goodfellow, and S. B. Waters, the Museum has been enabled to acquire a further three Chinese bronzes. All these gifts are gratefully acknowledged.

General: The Auckland Museum, founded in 1852, and The Auckland Institute, founded in 1867, were amalgamated in October, 1869, under the title "The Auckland Institute and Museum." The amalgamated institution will therefore complete the first seventy-five years of its life in October next. The site in Princes Street of the first building occupied by the Institute and Museum was granted by the Auckland Provincial Government, and at a later date the Provincial Government made a gift of £2,200 for extensions to that building. When the present magnificent building was erected the New Zealand Government made a substantial contribution towards its cost, and many friends, both in New Zealand and elsewhere, have made valuable donations. But it can be said with pardonable pride that for the most part this great cultural and scientific institution has been created and maintained by the efforts of the people of Auckland and surrounding districts.

Nevertheless there has always been a struggle to make ends meet. The total revenue for this year was £8,276, of which subscriptions yielded £447, interest on investments £1,297, and contributions from local bodies £5,700. An increased revenue is urgently needed and a Committee has been set up to consider ways and means of obtaining it. If, as seems probable, it is necessary to approach the public for funds either directly or through local bodies, the Council has confidence that the response will be a generous one.

Institute Meetings: The restoration of the Monday evening public lectures received good support from members. Of the four given, two were arranged in conjunction with the University College, and Dr. Briggs' lecture was made the occasion of a presentation to him of the Hector Medal. The thanks of members for the lectures given are due to:—Mr. W. R. McGregor, "Some Aspects of the Territory of New Guinea"; Dr. L. H. Briggs, "Hormones: Chemical Growth Substances of Plants and Animals"; Lieut.-Colonel W. Wesley Clemesha, "Some Historical Outbreaks of Malaria"; Count K. Wodzicki, "The Homing Instinct in Birds."

Sunday Lectures: The popular lectures in the Museum on Sunday afternoons were again well received. For once they were entirely on overseas subjects, chiefly dealing with areas that are of special interest through the war. Mr. R. B. Sibson, "Wanderings Among the Isles of Greece"; Mrs. Olwyn M. Turbott, "Micronesia"; Dr. Lai-yung Li, "China's Part in the War"; Mr. H. A. Wood, "Snakes"; Mr. R. B. Sibson, "The Mainland of Greece"; Lieutenant J. W. Kealy, "Impressions of the Middle East."

HAWKE'S BAY BRANCH OF THE ROYAL SOCIETY OF NEW ZEALAND, NAPIER. FOUNDED 1874.

President: I. J. Pohlen, M.A.

Hon. Secretary: C. F. H. Pollock.

The following is the seventieth Annual Report, for the year ended December 31st, 1943.

Meetings: The annual one took place on March 25th, and two meetings of the Council were held.

Addresses: On February 23rd, by Mr. B. Given, B.Sc., entitled "Parasite Control of Insect and Plant Pests"; and on October 27th, by Mr. R. Danvers, B.Sc., entitled "Canning and De-hydration in Hawke's Bay."

Membership: This numbers 54 at date.

Financial: The accompanying balance sheet shows a credit of £14 1s 9d for the year under review.

Hon. Auditor: The resignation of Mr. J. E. Gleadow was received with much regret, and the highest appreciation of his services, extending over 20 years, was recorded.

New Members: Elected were Messrs. W. H. Hill (Taupo) and C. N. Mitchell and J. S. Peel (Napier).

Paper for Publication: A further paper by Mrs E. A. Hodgson, being "A Review of the N.Z. Species of Plagiochila," has been submitted to the *Transactions* with the unanimous approval of the Council.

Library: To the Loan Collection have been added 21 early New Zealand volumes from the Napier Museum, and 55 volumes from the Police Office, Napier, for which grateful thanks are recorded by the Society.

New volumes purchased are: *Landscape* (Cotton), *Soil Erosion* (Ayres), *Social Relations of Science* (Crowther), *The Virus—Life's Enemy* (Smith), *Man and His Nature* (Shrimpton), *Physics and Philosophy* (Jeans), *Young Offenders* (Carr-Saunders), *New Zealanders and Science* (Jenkinson).

Council: Members on active service are Drs. A. Clark and G. Waterworth.

I. J. Pohlen, *President*.

THE WELLINGTON BRANCH OF THE ROYAL SOCIETY OF NEW ZEALAND (INC.).

Seventy-sixth Annual Report, being the Report of the Council for the Year Ended 30th September, 1943.

Membership: The total membership now stands at 229. There were 17 new members elected during the year, 3 resignations were received, 3 members were transferred to other Branches, and 3 members whose subscriptions had been outstanding for over three years were struck off the books of the Society. Two members whose correspondence has been returned through the post have been temporarily removed from the books. The Council also desires to record its sorrow at the death of our esteemed member, Major E. R. Christie.

Syllabus: Prior to the drawing-up of the syllabus for the year the Council issued a questionnaire to members. This, although not receiving quite the response that was desired, gave a good cross view of the desires of members of the Society with regard to the nature, duration, and subjects of meetings, meeting places, etc., and was made good use of during the final preparation of the year's syllabus.

Meetings: The Society and the Sections have continued to meet at Victoria College, and the Council desires to record its thanks to the College Council for the facilities which so willingly have been placed at the disposal of the Society. The following general meetings have been held:—April 28th, Presidential Address by Mr. R. L. Andrew, "Forgotten Scientific Worthies"; May 26th, "Public Health Services in the U.S.A.," by Lieut.-Colonel T. F. Durham, Director of Food Inspection Branch, U.S. Armed Forces; June 23, "Demonstration: "Pedology," by Drs. L. I. Grange and J. K. Dixon; "Petrology," by Dr. C. O. Hutton; "Palaentology," by Dr. J. Marwick; July 28th, Symposium, "Population Problems," introduced by Mr. L. S. Hearnshaw and Mr. A. Leigh Hunt; August 25th, "Agricultural Research in Virginia," by Dr. Harold T. Cook, Chief of the Plant Pathology Department, Virginia Crop Experimental Station, Norfolk, U.S.A.; September 22, Symposium, "The Ultimate Power Possibilities of the Waikato River," introduced by Mr. G. P. Anderson, Mr. J. Healy and Mr. N. Modriniak.

Sections: The Astronomical Section held one meeting during September in co-operation with the Carter Observatory Board, when Lieut.-Colonel F. J. N. Stretton spoke on "Novae." The Biology Section has held the following meetings at which attendance has been relatively good:—October 13th, 1942, "The Visibility of Objects," by Mr. L. S. Hearnshaw; May 4th, Chairman's address, by Mr. J. T. Salmon, "Biology and the Future"; June 2nd, "Microbes and the Soil Microclimate," by Dr. I. D. Blair; July 6, "Investigations of New Zealand Fish Oils," by Dr. F. B. Shorland; August 3rd, "Public Health Aspects of the Venereal Disease Problem," by Dr. H. Smith; September 7th, "Can the Art of Cheesemaking be Made a Science," by Dr. W. Riddet. The Geology Section has held six meetings, at which the following papers were read:—10th September, 1942, "The Topography and Geography of the New Guinea-Papua War Zone," by Mr. M. Ongley; and "The Te Anau-Clinton Unconformity at Albert's Cap," by Dr. C. O. Hutton; 8th October, "The Geological History of the Dannevirke Subdivision," by Dr. A. R. Lillie; 20th May, 1943, "Problems Connected with the Metamorphism of the Otago Schists," by Dr. F. J. Turner; 6th June, "Clarendon Phosphate," by Mr. E. O. Macpherson; July 8th, "Stratigraphy and Structure of Part of the South Island," by Mr. H. E. Fyfe; 12th August, "The Mechanism of Vulcanism, Part 1, by Professor C. A. Cotton. In addition, two papers were read by title for publication at meetings of the Sect'on, and a number of exhibits have been shown. The Technological Section has held six well-attended meetings at which the folowing paper was read:—October 21st, 1942, Chairman's address, "Possibilities of Wind Utilisation for Energy Production," by Mr. H. S. Lamburd. A new and much-appreciated activity of the Section has been the arranging of visits to the various factories and places of interest, two of them having been held on regular meeting nights and one—the National Electric Company, as an extra meeting. The May and July meetings were visits to the factories of Godfrey Phillips (N.Z.), Ltd., and Standard Telephones and Cables, Ltd., respectively. Social Science Section: This, the youngest of the Sections, held its inaugural meeting on the 11th May, with an address by the Hon. Walter Nash on "Problems of Post-war Reconstruction." Other addresses have been—June 8th, "Recent Advances in Science and Their Social Implications," by Mr. J. W. Matthews; July 13th, "Plans for Post-war Rehabilitation in New Zealand," by Mr. J. S. Reid; August 10th, "Emotion and Bodily Disease: the Principles of Psychosomatic Medicine," by Dr. R. W. Medlicott; September 14th, "Plans for Post-war Education in New Zealand."

Papers for Publication: The following papers were read by title for publication in *The Transactions of the Royal Society*:—October 28, 1942, "A Physical and Chemical Investigation of the Ketetahi Hot Springs Area of Tongariro National Park," by Mr. S. H. Wilson; "New Records of Collembola from New Zealand, with Descriptions of New Species, Part II, Symphypleona," by Mr. J. T. Salmon; "The Collection, Preservation, and Study of Springtails (Insects of the Order Collembola)" by Mr. J. T. Salmon; "Revision of the Genus *Algidia* Hogg, with Descriptions of New Species (Order Opiliones), by Mr. R. R. Forster; "The Upper Winds of Little America," by Mr. C. E. Palmer; February 1st, 1943, "Some Features of Heavy Mineral Separations," by Dr. C. O. Hutton; May 26th, 1943. "The Genus *Folsomia* in New Zealand (Collembola)," by Mr. J. T. Salmon; July 28th, 1943, "Some Inter-tidal Sessile Barnacles of New Zealand," by Miss L. B. Moore; August 25th, 1943, "Certain Changes in the Nomenclature of New Zealand Species of Graminae," by Mr. V. D. Zotov; September 22nd, "Revision of the Indigenous Grasses of New Zealand," by Mr. V. D. Zotov.

Representation of the Standing Committee of the Royal Society: Following upon his election as President of the Royal Society, Dr. H. H. Allan resigned his position as this Branch's representative, and Mr. R. L. Andrew was appointed by the Council in his place.

Other subjects under discussion with the Standing Committee include: The publication of University theses, the poor quality of the paper on which recent numbers of the *Transactions* have been printed, the re-opening of the Dominion Museum, and memorial to past famous New Zealand scientists.

Wild Life Conference: The following two representatives have been appointed by the Council to represent this Branch at the forthcoming conference being convened by the Royal Society of New Zealand to discuss Wild Life Control in New Zealand:—Mr. J. T. Salmon and Mr. V. D. Zotov.

Science Teaching in Schools: The Council felt that the Royal Society Standing Committee had not done all it could have done in the matter and has requested the Standing Committee to re-open the matter with the Government Department concerned.

Library: Periodicals continue to come to hand at irregular intervals. The publication of *Discovery* was resumed during the year, and the first six numbers have arrived in the library. The following books have been purchased:—*On the Way to Electro-war*, by Doberer; *Science—A New Outline*, by Sullivan; *The Serial Universe*, by Denne; *Man's Conquest of the Air*, by Harper; *What Engineers Do*, by Binger; *Instincts of the Herd in Peace and War*, by Trotter; *Keeping Cool*, by Haldane; *Astronomy for Everyman*, by Proctor; *Atoms and Stars*, by Eddington; *Wolf Child and Human Child*, by Gesell; *Quest, the Evolution of a Scientist*, by Infeld; *Medicine and Mankind*, by Sorsby; *The Romance of England's Forests*, by Dowsett; *Man Against Microbes*, by Bigger; *War on Wheels*, by Katz; *A Guide to Modern Wickedness*, by Joad; *Philosophy for Our Times*, by Joad; *The Uniqueness of Man*, by Huxley; *Parachutes*, by Low; *The Story of Astronomy*, by Lockwood; *Your Allergy*, by Cohen; *The Power Behind the Microphone*, by Eckersley.

Observatory: The Astronomical Section reports that the Observatory is in a satisfactory state of repair.

For and on behalf of the Council,

R. L. Andrew, *President*.
J. T. Salmon, *Secretary*.

THE NELSON INSTITUTE.

Your Committee has much pleasure in presenting the Annual Report and Statement of Accounts for the 101st year since the founding of the Nelson Institute in 1841—i.e., for the year ended 31st December, 1943, as the Institute was not actually opened till 1842.

Committee: During the year Mr. J. Glasgow, the Vice-president, was reluctantly obliged to resign his seat on the Committee, and in his stead Mr. H. Hurst was elected to the deputy office. Later in the year, when Mr. S. MacArthur moved h's residence to Blenheim, the vacancy was filled by the appointment of Mr. E. R. Neale as a representative of the Nelson City Council. The required number of nominations being secured for the Committee seats, no election was held. Attendances at the Committee meetings were as follows:—*City Council representatives*—H. Hurst 10, N. Rout 6, W. S. Street 5, MacArthur and Neale 4; *Subscribers' representatives*—Sir Walter Scott 11, Mrs. A. S. G. Adam 9, Miss B. W. Rhodes 9, Miss D. Hayes 10, Mr. A. J. Gray 8, Mr. I. S. Gardiner 9, Mr. J. W. Russell 10.

At the previous Annual Meeting Lieut.-Colonel H. C. Burton severed his connection with the Commimttee after holding the office of Secretary continuously for 25 years. The Committee wishes to place on record his long term of faithful devotion to the Institute, a service that definitely promoted the stability of this important public institution. The Committee also wishes to record the valuable aid rendered by Mr. Glasgow during his many years as a member of the Committee and an enthusiastic worker for the Institute.

Subscribers: The record number of 1,287 on the books on 31st December, 1943, was made up as follows:—Adults and students 702, children 460 (an increase of 44), active rental—i.e., the regular rental clients, 125. The increase in subscriptions taken, from £555 7s 6d to £698 18s 6d, and in fees for extra books from £230 8s 11d to £304 18s, tends to emphasise the ever-growing popularity of the Library. While the lighter fiction appears to be the popular demand and possibly much of the item £304 18s for extras comes from readers of this type of literature, the Committee notes with distinct pleasure that there has been a somewhat keener demand for the better class of books.

Books, Periodicals and Newspapers: During 1943, 1624 books were added to stock, as compared with 1,023 for 1942; the accessions comprising 701 fiction, 456 general literature, 467 juvenile. The stock now consists of some 22,000 books. During the year the committee has been alive to the need for building up the general literature and reference sections, but the inadequacy of N.Z. stocks with respect to superior literature and the vagaries of overseas supply have allowed only limited progress. A sound and well-balanced library can be built only by selection and indenting.

The library subscribes to 65 different periodicals, providing 86 issues available, of which 6 are juvenile, newspapers number 26 are for 1942.

Children's Department: This branch shows very promising progress for the year. It now contains 2,435 books, and its own earned income touched £75 for the year. It was officially visited by two representatives of the Nelson Education Board, who expressed themselves as gratified by the facilities offered, but regretted that fuller use of the library was not made by more of the Nelson boys and girls.

NELSON PHILOSOPHICAL SOCIETY.

Annual Report for Year Ended 30th September, 1943.

The Committee presents the following report on the activities of the Nelson Philosophical Society for the year ended 30th September, 1943:—

The membership of the Society consists of 31 full members, including two recently transferred from the Wellington Branch of the Royal Society, and 19 Associate Members, making a total of 50—an increase of seven on last year's number.

Six successful meetings have been held during the year, the average attendance of members and visitors being about 50.

The following was the programme of addresses for the session:—

1942: 24th October (Annual Meeting), Mr. T. A. Glendinning, "Fermentation and Its Application to Arts and Industries."

1943: 17th May, Presidential address by Mr. F. G. Gibbs, "Early Man"; 21st June, Dr. D. Miller, "Mosquitoes and Malaria; 19th July, Sir Theodore Rigg, public address in the Marsden Hall, "Twenty Years of Agricultural Progress in the Waimea County"; 9th August, Dr. R. O. Page, "The History and Manufacture of Leather"; 27th September, Mr. C. I. Kidson, "The Road to the Andamans."

F. G. Gibbs, *President*.
William C. Davies, *Hon. Secretary*.

OTAGO BRANCH OF THE ROYAL SOCIETY OF NEW ZEALAND.

Annual Report for Session 1943.

Membership: The number of full members for 1943 was 150, as compared with [illegible] for 1942. There were 9 new members, 3 resignations, 3 deaths and deletions.

Deaths: The death in action is recorded of Flying Officer J. M. Paape, one of the youngest and most promising of our members.

The death is recorded with regret of Miss H. K. Dalrymple, B.A., an enthusiastic botanist.

The Late John Scott Thomson: The following minute, drawn up by Dr. J. E. Holloway, F.R.S., and Dr. F. J. Turner, is placed on record:—

Mr. J. Scott Thomson was a very active member of this society for many years, and a constant attender at the regular meetings. He was on our Council almost continuously from 1928 onwards. He refused nomination for the position of President, but was elected Honorary Vice-president for 1942. On a number of occasions he gave addresses to the society and to the Junior Branch illustrated by his magnificent lantern slides on the vegetation of New Zealand and especially on that of the high mountains.

In conjunction with Mr. George Simpson, he successfully carried out very extensive and varied botanical investigations. These were published in some 14 papers in the *Transactions of the Royal Society of New Zealand*, and in other New Zealand or overseas journals. These papers constitute a valuable contribution to New Zealand Botanical Science. The field work involved in these investigations was such as demanded long-continued and accurate observations, and considerable experimental work. The two men covered a large part of the South Island, some of their expeditions being of a very arduous nature such as would be beyond the physical powers of any but the strongest. It can be mentioned here that Mr. Thomson in his younger days represented Otago in Rugby football.

It is impossible on this occasion to refer in detail to the varied botanical activities of Mr. Thomson and Mr. Simpson. They included the general ecological study of mountain and of forest vegetation, the collection of plants for the garden and for transmission to other botanists, the very successful photography of vegetation, the study of special groups of wild hybrids, the determination of the specific acidity of the soil under different types of forest trees and the precise nature of the competition between *Nothofagus* and the mixed subtropical forest.

Mr. Thomson also played a valuable part in interesting the general public by means of his many popular addresses on the native vegetation of this country. Among other addresses he gave the annual Banks Lecture to the Royal New Zealand Institute of Horticulture in 1935. In 1936 the Loder Cup was presented to him in conjunction with Mr. Simpson for meritorious work on the New Zealand flora. The two men collaborated for a number of years with the late Dr. Cockayne, F.R.S., and with Dr. H. H. Allan, of the Plant Research Bureau. Mr. Thomson's private garden comprises one of the most valuable collections in existence of native plants, and many New Zealand and overseas botanists have been able to study these plants there under his guidance.

Attendance: Numbers attending the public meetings were 20, 60, 25, 61, 25, 20, 70, 20. Of these the second was a joint meeting with the Dunedin Field Naturalists' Club, and the seventh a joint meeting with the Otago Branch of the New Zealand Institute of Chemistry. Apart from these two meetings the adverse effect of the war on the attendance was evident.

Representatives on Council of Royal Society: The thanks of the branch are again due to Drs. C. M. Focken and F. J. Turner, representatives of the Council.

Representatives on Museum Management Committee: At the beginning of the year Messrs. G. Simpson and J. Scott Thomson represented the branch. The late Mr. Thomson's place has now been taken by Mr. L. E. Richdale.

Whero Island: The branch has collaborated with the Southland Branch in seeking from the Lands and Survey Department permission to erect a building for the study of native birds. Permission has now been granted and the council of the Otago Branch has authorised payment of a grant of £10 towards the erection of the building.

Auditorium Fund: This now stands at £1,573 16s 4d.

War Funds: The Branch has invested £100 in the National Savings Account.

Microscopic Section: Due to war conditions meetings were restricted to one at which demonstrations were provided for juniors.

Astronomical Section: Eye pieces were borrowed to replace those stolen. The observatory was opened on the public nights and was visited by parties from Taieri Aerodrome, Boy Scouts and Girl Guides.

Junior Lectures: The average attendance was 62, a decline due as much to additional school work as to war conditions. Four evenings. Microscopic Section, demonstration; Dr. T. McKibbon, public health; Miss E. J. Batham, M.Sc., parasites; Dr. R. Gardner, plastics.

Main Programme: April 13, Presidential Address, "Scientific Method and World Affairs." May 11, Roger Duff, M.A., Canterbury Museum, "Excavation of Moa-hunter Burials at Wairau Mouth." Joint meeting with Dunedin Naturalists' Field Club. June 8, Refrigeration in New Zealand—(a) History, E. Hayes, M.A.; (b) Technique, W. A. Partridge. July 13, Symposium—"Ancient Land Connections in New Zealand"; Geology, Dr. W. N. Benson, F.R.S.; Botany, Dr. J. E. Holloway, F.R.S.; Zoology, Professor B. J. Marples. August 10, J. Harris, B.A., "Recent Trends In Library Organisation"; microfilm. September 14, G. Stratford, "A Synopsis of the Fruit Industry In New Zealand." October 12, Papers reporting original work—Professor B. J. Marples, "Fossil Penguins"; L. Gurr, "A Method of Recording Bird Behaviour." Dr. H. D. Skinner, "Decorative Design on Fijian Pottery Water Vessels." November 9, Annual General Meeting. Recent Museum Accessions.

Original Papers: E. J. Batham, M.Sc., "The Vascular System of New Zealand Species of *Gunnera*"; Sir William Benham, F.R.S., "The Octopodus Mollusca of New Zealand, Part IV"; J. T. Linzey, "Hydrography of the Estuary of the Avon and Heathcote"; L. E. Richdale, "The White-faced Storm Petrel or Takahi-kare-moana (*Pelagodroma marina maoriana* Mathews), Parts I, II, III," "The Titi Wainui or Fairy Prion (*Pachyptila turtur* Kuhl). Parts I and II."

THE CANTERBURY BRANCH OF THE ROYAL SOCIETY OF NEW ZEALAND.

Annual Report for the Year 1943.

The Council submitted the following report of the year's work to the Annual Meeting, held on Wednesday, December 1, 1943:—

Council: Ten ordinary and one special meeting of the Council have been held during the year. Early in the year Dr. R. A. Falla, one of the Branch's

representatives on the Council of the Royal Society of New Zealand, was granted leave of absence because he was away from Christchurch. Dr. R. S. Allan, as the second representative, was unable to attend meetings. He therefore resigned, and Dr. O. H. Frankel was elected in his stead. The vacancy on the Council which thus arose was filled by Dr. Allan, who agreed to serve on the Council as an ordinary member.

Membership: Losses by resignation have been four in number, and by death seven. Against these losses must be placed 13 new members elected during the year, including one transferred from associateship, making a total membership of 133. Two new associates have been elected, making a total of nine associate members, several of whom are on active service.

Obituary: The Society deeply regrets the loss by death during this year of the following members:—Dr. C. Coleridge Farr, Dr. H. G. Denham, Professor J. E. L. Cull, Mr. Orton Bradley, Mr. S. G. Ridley. Several of these members had played large parts in the activities of the Society and references to them and to their work have already appeared in the *Transactions*.

Programme: A full programme of activities for the year was planned by the Council, the main item being a series of addresses on various aspects of post-war reconstruction. The attendance at these meetings varied considerably, some being largely attended. The Council feels that this was a worth-while activity. In addition two further series of meetings were largely attended. Dr. K. R. Popper gave a series of lectures on Scientific Method, which were followed by profitable discussions. Three discussions, introduced by brief addresses, on "The Organisation of Scientific Research in New Zealand" were arranged in co-operation with other societies. These meetings were felt to be very useful.

The following addresses were given in the Society's main programme:—March 3, Presidential Address, "The Idea of Race," Dr. I. L. G. Sutherland; April 7, "The Social Responsibility of the Scientist," Dr. H. N. Parton; June 2, "Symposium on Economic Aspects of International Reconstruction," Mr. J. Danks, M.A., Professor A. H. Tocker, Mr. G. Manning, M.A.; July 8, "Political Aspects of International Reconstruction," Mr. A. C. Brassington, LL.B.; September 1, "Education in the Post War World," Dr. C. E. Beeby; October 6, "Some Problems of Rehabilitation," Major R. D. Cox.

Three ordinary meetings were held:—May 5, Paper, "Wairau Moa Hunters," R. S. Duff, M.A.; exhibit, "Mineral Fluorescence," Dr. R. S. Allan; August 5, Paper, "Post Glacial Climatic Changes in South Canterbury," Mr. J. D. Raeside, M.Sc.; Paper, "The Development of Terebratella inconspicua III," Professor E. Percival; both these latter papers were read for publication in the *Transactions*; November 3, Paper, "Some New Facts and Old Fallacies About Earthquakes," Mr. H. F. Baird, M.Sc.

Wild Life Control: During the year a letter was received from the Wild Life Committee of the Royal Society of New Zealand asking that a meeting be called of interested bodies in Christchurch to discuss the control of wild life in New Zealand. Arrangements and discussion concerning this meeting claimed a good deal of the Council's attention, although the diversity of the interests involved prevented effective recommendations being made by the meeting which was called.

Hon. Librarian's Report: Since the last Annual Report, much of the moving of the Society's Library, in terms of the merger agreement with the College signed in 1942, has been done. Practically all bound volumes of journals (other than duplicates) have been placed on the shelves previously reserved for them in the proper subject classification of the College Library. They have all been catalogued and recorded in detail in the Society's library accession book. Individual books have also been catalogued briefly, classified and labelled, and are now being moved. All volumes bear the Society's bookplate. Unbound journals are still in their old location, but a start has been made to complete and bind many of the most important volumes. This will be a slow process, as it is not easy to get missing issues overseas, and there is also congestion at the bindery.

As a result of a special campaign to sell the Society's publications, a considerable sum has been raised, and much of this has been added to the binding fund. Many issues of our journals have in the past been taken out without record. Their prompt return would save us from buying fresh copies unnecessarily.

A number of members are making good use of the College Library, while staff and students are finding it a convenience to have easier access to the Society's Library. There are still, however, many members who do not make use of the combined libraries. In particular, members outside Christchurch could make use of the postal service now available.

Riccarton Bush: The Board of Trustees of Riccarton Bush reports that the operations during the past year have been mainly confined to general maintenance. Several improvement projects are being considered and will probably be carried out next year.

The bush has continued to be a source of attraction to visitors and to student parties from schools and colleges. The Board desires to comment on the highly satisfactory manner in which the resident ranger, Mr. Leonard Armstrong, has carried out his duties.

Field Club Section: During the year the Field Club Section held a meeting and decided that owing to absence of so many members on war service, the Club should go into recess.

I. L. G. Sutherland, President.
R. M. Allison, Secretary.

THE SOUTHLAND BRANCH OF THE ROYAL SOCIETY OF NEW ZEALAND.

Annual Report for the Year 1943-44.

President: Dr. C. C. Anderson.

Secretary: Mr. A. D. Nisbet.

Membership: The year began with a membership of 46, of whom five are on active service and one is a life member. During the year seven new members were admitted and four members tendered their resignations, so that we now have an active membership of 44, plus five on active service, making a total of 49.

Attendances: Attendances at meetings early in the season were very poor, but improved considerably towards the end of the session, the average of the last three meetings being about 25. Of these attendances, however, a large number were friends and not members.

Native Bird Work: During the year another small amount of work has been done in connection with the destruction of cats on Herekopare Island. The total number of cats destroyed to date is 88. We had hoped to have had this work finished by this time, but unfortunately it has not been possible owing to war-time conditions. During the year, also, we undertook to assist Mr. Richdale's work on Whero Island by having a hut erected for him. The hut has been erected and the public and other interested bodies have been asked to assist in financing the project. As in the case of Herekopare, the response has been generous, and we are hopeful that in the near future the hut will be debt-free and that we shall have a surplus with which to finish the place with shelves, cupboards, etc.

Wild Life Control: A report having been received that rabbits had been released on Stewart Island, we took immediate action to have them removed. The result of our activities has been that the Government has sent a trapper over to Stewart Island and this work of destruction is proceeding, if it has not yet been completed.

Lectures: A delightful series of lectures was given during the session. They were as follows:—April 29, Dr. C. C. Anderson (Presidential Address), "Evolution of X-rays"; May 7, Mr. L. E. Richdale, "Bird Life on Whero Island"; June 17, Dr. J. E. Holloway, "Desert Vegetation"; July 29, Miss M. Fyfe, "You and Heredity"; August 23, Mr. R. Willett, "Minerals in War"; October 28, Dr. H. D. Skinner, "New Light on Ancient Races and Cultures"; November 2, Professor B. J. Marples, "The Story of Life in the Past"; November 18, Dr. H. Soper, "Chemistry and Society."

Our thanks are due to these people for the valuable assistance they have given us.

Conclusion: Although times are difficult our branch continues to grow steadily, if slowly. We have enjoyed success in our efforts during the past year, and the forthcoming session promises to be equally as successful. To grow must be our slogan, and to do so we must make every effort to increase our membership. We must also have large attendances at our meetings, so that every member is urged to be present as often as possible.

PRESIDENTIAL ADDRESS

DR. H. H. ALLAN.

Since the previous annual meeting we have lost two distinguished honorary members.

Frederick Chapman was elected in 1932. Born in London in 1864, he served in the geological department of the Royal College of Mines from 1881 till 1902, when he went to Melbourne as palaeontologist to the National Museum, a position he held till 1927. He then became Commonwealth palaeontologist, retiring in 1936. His death on December 19, 1943, ended a long and fruitful career. While becoming a leader and a recognised authority in his profession he was interested and versed in nearly all aspects of natural history. His name will ever endure as one who inspired and encouraged others to take up the studies he so loved himself. To him we owe several valuable palaeontological papers in our *Transactions*.

Sir Edwin Butler, F.R.S., was elected in 1939. Born in 1874, he devoted his life to advancing the study of economic mycology in the Empire. As Imperial Mycologist to the Agricultural Research Institute at Pusa, India, he rendered great service, and no more fitting person could have been chosen to be the first Director of the Imperial Mycological Institute at Kew. The great developments within the Empire of work on and institutions for the furthering of economic mycology are very largely due to his energy and guidance. Very helpful in this regard was his visit to New Zealand in 1923. His was an outstanding and arresting personality, whether he were at the lecture table or directing the affairs of his Institute. His death in April last removed an Empire leader in science.

I wish also to pay tribute to the late **Sir Albert Seward, F.R.S.**, who was elected in 1928. Born in 1863, he early on devoted himself to the study of fossil plants and their significance in evolution. His masterly work on the mesozoic floras of the world gained him widespread renown, and he became a commanding figure in the scientific life of Great Britain. Gifted as he was with a beautiful voice, skilled as he became in clear and vivid expression, his influence spread far beyond the confines of academic and scientific circles. For many years head of the Botany School at Cambridge, and Master of Downing College, he became Vice-Chancellor of his University, and proved that a great scientist may be also a great administrator. His death in 1941 came at the plenitude of his powers.

SEVENTY-FIVE YEARS OF "THE TRANSACTIONS."

On October 10, 1769, scientific work in New Zealand began when Solander and Banks strolled along the Waikanae River at Poverty Bay. At Wellington, one hundred years later, on May 5, 1869, James Hector signed the preface to the first volume of our *Transactions*, and regular publication of the results of study ensued.

seventy-five years it seems well to review the progress made, so far as it is reflected in the published papers, and to consider the outlook for the future.

In his inaugural address to the Institute, His Excellency Sir George Bowen, on August 4, 1868, outlined the character and objects of the Institute as stated in the preamble to "The New Zealand Institute Act, 1867." "It is expedient to make provision for carrying out the geological survey of the Colony and to establish and incorporate a public institution in the City of Wellington to be called "The New Zealand Institute" which Institute shall comprise a public museum and laboratory and a public library. And it is also expedient by means of lectures, classes and otherwise to promote the general study and cultivation of the various branches and departments of art, science, literature and philosophy."

Sir George went on: "Co-operation is the secret of success in all scientific pursuits, and the New Zealand Institute, while leaving its affiliated societies unfettered in the performance of their separate functions, will publish their chief transactions on a uniform plan, thereby concentrating the information collected by local observers throughout the country, and providing for the preservation, in a permanent and accessible form, of the results of their labours."

"Let me remind you," he said, "that the main object of the Legislature in founding this Institute was not merely to make provision for healthy intellectual recreation, but rather to provide guidance and aid for the people of New Zealand in subduing and replenishing the earth—in the heroic work of colonisation."

Sir George referred particularly to the geological, botanical, zoological and physical sciences. He also stressed the value of work on the ethnology and anthropology of the Maori race, and on the encouragement of technical and scientific education. "I fully believe," he added, "that the New Zealand Institute contains within itself a sure principle of vitality because it contains a sure principle of usefulness."

The first volume gave us a magnificent start, and those great essays of Hector, Monro, Travers, Buchanan, Buller, Colenso, Ludlam, Crawford, and Shortland we may still read with enjoyment and profit. In the first volume, too, Hector gave that famous list of thirty-one subjects "in the hope that it may be found useful as suggesting future communications to the various societies." This list largely aimed at exploiting the natural resources of the country, the development of agriculture, horticulture and forestry, and the advancement of civil engineering and public health; but fundamental work in botany, geology, zoology, and anthropology received some mention. Every one of these thirty-one subjects still requires and is receiving serious attention to-day: "formation of sandbanks in rivers, and bars to harbours," "habits of animals, especially of those destructive to trees and cultivated plants," "resources of the Colony in cements, concretes, plasters, building stones," "causes of failure of introduced grasses on some of our soils," "medicinal plants," "harbour improvements," and so on:

Sir William Jervois, in his anniversary address for 1883, said: "I am happy to say that there is not one of these subjects that has not

been not merely touched on, but very carefully gone into; in fact, I greatly doubt whether any young country in the world has been so systematically investigated as New Zealand has been under the auspices of this Institute." There is some exaggeration in this, but exaggerated also is the statement of Cockayne in 1919, referring to Hector's list, that "there is hardly a mention of those subjects which have filled most of the fifty volumes" of the *Transactions.* Do we not find many papers on the "History, mythology, ethnology, etc., of the Maori race," on "mineral and metalliferous deposits," on "the occurrence of rare plants, animals and minerals," on "localities for fossils"? It was natural that at that early stage Hector should throw into relief matters that would attract the attention of the layman and of those who would have to provide the funds. I am afraid it is still necessary to-day to do somewhat as Hector did. Naturally, also, many of the topics mentioned received attention rather in departmental reports and special technical journals than in the pages of the *Transactions,* leaving us more free to publish basic work. This is all to the good, if only we can rest assured that the matter published will be recognised by those who control our finances as essential and not merely frills.

An analysis of the contributions so far made should be of interest: We find that the three sciences—Zoology (1470 papers), Botany (784), and Geology (752)—account for over 75 per cent. of the papers published. If we include the 249 papers on palaeontology (all too few deal with palaeobotany) and the 19 papers on the organic chemistry of indigenous plants we have 65 per cent. of the total dealing with biological matters. Zoology reached its peak, so far as number of papers goes, in the fifth lustrum, when 146 papers were published. There was a distinct drop in the thirteenth lustrum, when 42 papers were published. Publication has since been maintained at about that level. Botany had its maxima in the third and sixth lustra, in each of which 88 papers were published. In Botany, too, there was a distinct drop in the thirteenth lustrum, the papers averaging from then on about 30 per lustrum. Geology had its maximum in the eleventh lustrum, with 81 papers, and has since averaged about 55 papers per lustrum. The year 1930, then, appears to have been a turning point in all these subjects, but they still maintain predominance over other subjects.

Chemistry has accounted for 214 papers, with a maximum in the first lustrum, with also a marked drop from 1930 onwards. The total of papers for physics is 67, for meteorology 17, for seismology 18, and for oceanography 8. Physics was more to the fore from 1893 to 1898 than at any other period, while astronomy, with 49 papers, appears to be maintaining the average of 3 per lustrum.

Anthropology and ethnology have 151 papers to their credit, but only three have appeared since 1924. The figures for other subjects are: philology 21, but only two since 1903; economics 11, scattered throughout the volumes till 1927; medicine 19, but only two since 1903; geography 27, the last appearing in 1907; history 60, the last in 1924; education 19, the last in 1905; mathematics and

statistics 46, the last in 1918; philosophy 23, the last in 1908; literature 10, but only one since 1911. Engineering topics made their best showing in the first three lustra, when 49 of the 61 papers were published, the last appearing in 1917. Some 28 papers defy classification except as "miscellaneous," but since 1908 only two come under this head.

Roughly grouping the different subjects we get the following totals for the successive decades:—

	1st Decade	2nd Decade	3rd Decade	4th Decade	5th Decade	6th Decade	7th Decade	Totals
Natural History	455	521	509	402	411	418	280	2996
Physics and Chemistry	88	56	59	47	45	45	16	356
Pure and Applied Mathematics	43	18	6	23	17	0	0	107
Humanistic Studies	55	58	74	79	21	24	3	314
Miscellaneous	5	1	6	14	2	0	0	28
Totals	646	649	656	568	496	487	299	3801

The average number of papers per volume for these groups in different periods is:

Natural History—1869 to 1898, 50; 1899 to 1929, 40; 1930 to 1944, under 30.

Physical and Chemical Subjects—1869 to 1883, 9; 1884 to 1929, 5; 1930 to 1944, under 2.

Pure and Applied Mathematics—1869 to 1883, 4; 1844 to 1918, 1; 1919 onwards, a trace.

Humanistic Studies—1869 to 1903, 7; 1904 to 1924, 4; 1925 onwards, a trace.

The average number of papers per volume for all subjects is for the period 1869 to 1883, 67; for 1884 to 1898, 64; for 1899 to 1913, 54; for 1914 to 1929, 49; for 1930 to 1944, 30.

I have not attempted to analyse the relative length of papers in the successive volumes; long and short papers occur throughout, but the trend seems clear for long rather than short papers to be offered for publication. In sum, there have been 3899 papers contributed by over 800 authors.

In interpreting these figures we have to remember the changes that have been made in format, and especially that various other avenues of publication have opened up since the *Transactions* began; for example, the *Journal of the Polynesian Society* in 1892, the *New Zealand Journal of Agriculture* in 1910, and the *Journal of Science and Technology* in 1918. Further, there have been increasing facilities for publishing in overseas journals. Cost of publication has increased, and available funds have not increased in proportion. By the Royal Society of New Zealand Act in 1933, the New Zealand Institute was abolished and there was constituted a "Body for the Promotion of Science, to be known as the Royal Society of New Zealand." Art, literature, and philosophy were no longer our concern. Indeed, the Act of 1903 mentions only science as coming under

our purview. In view of all these points we can understand the gradual restriction of the *Transactions* to a limited number of sciences.

Bishop Williams, in his presidential address for 1937, stated that two criticisms of the *Transactions* had come to his notice:—that the papers were too technical, and that there was not sufficient variety in the subjects treated. "The answer to the first," he said, "is simple. If a paper is to be of value to the scientific reader it must of necessity be technical. We would like to encourage readers of the *Transactions*, but mere popularity is not a legitimate aim of such a society as this." On the second count he remarked that "our field of operation would appear to be limited solely by our interpretation of the term 'science'." We are also limited, however, by what is offered for publication by our members. We may expect that within the next decade further journals dealing with scientific matters will be commenced in New Zealand. Already geographers and botanists, at least, are thinking in this direction. There seems little doubt that for some years to come our *Transactions* will continue on the same lines of those of the last 15 years, and geology, zoology, and botany will account for the bulk of the papers.

But quantity is not all. What of quality? Cockayne, in reviewing 50 years of work, said: "The greater number of papers which have appeared of recent years would have been accepted by the scientific journals of Great Britain and America, if the numerous papers strictly of local interest be excluded from the estimate." So far as I can judge, the same verdict is true of the papers published in the succeeding 25 years.

Let us recall some of the great contributors of the past, with the dates of their periods of publication:

Buchanan (1869 to 1888). Twenty-eight papers, mainly botanical; illustrations to the first 19 volumes. "He was a great explorer, or rather, wanderer, and he endured much hardship in collecting specimens of geological interest, minerals, birds even, and certainly above all other things, plants."—James Hector.

Buller (1869–1899). One hundred papers on zoology, mainly ornithological. "His papers had commanded the attention of scientific men not merely in New Zealand, but in Europe and America."—M. Chapman.

Colenso (1869–1899). One hundred and three papers, chiefly on botany and ethnology. "Colenso had been a constant contributor to the work of the New Zealand Institute. He took a lively interest in its progress, and in its success in every direction. He contributed to its meetings articles of the greatest interest and value upon almost every branch of natural science. He did valuable work as an explorer in the early days of the settlement of New Zealand, and then and subsequently he did good work as a recorder in zoological science. But above all things he did good work in extending the knowledge of the botany of New Zealand. But these were bypaths in comparison with his great work in philology."—Hector.

Crawford (1869–1888). Thirty-five papers, mainly geological. A man of lively intellect, interested in a wide range of subjects, and an ardent supporter of the Institute.

Haast (1869–1887). Forty-two geological papers. "Who, by his explorations and discoveries, has done so much both officially and privately to advance the intellectual and material progress of Canterbury and of the whole Colony of New Zealand."—Phil. Inst. of Canterbury.

Hector (1869–1903). Seventy-three papers on geology, zoology, botany. "By his own researches in geology, zoology and botany in the Dominion of New Zealand, he added greatly to the knowledge of these branches of science; as head of the Geological Survey, of the Meteorological Department, and of the Colonial Laboratory, and as Director of the Colonial Museum he was the chief scientific advisor of successive governments for a long period of years, while as Chancellor of the New Zealand University he was closely associated with the highest education of the Dominion."—G. M. Thomson.

Hutton (1869–1906). One hundred and eighty-four papers on geology and zoology. "By his long series of original contributions on the geology and zoology of New Zealand he established the knowledge of these subjects on a sure and permanent foundation, and made for himself a world-wide reputation as a geologist and zoologist, and by his researches on the origin of the fauna and flora of New Zealand became a recognised authority on questions of bio-geography."—C. C. Farr.

Kirk. One hundred and thirty-two papers on botany. "Whose scientific labours have contributed so largely to the advancement of the study of botany in New Zealand."—F. W. Chapman.

Travers (1869–1903). Thirty-eight papers on botany. "He was one of the chief promoters of the New Zealand Institute in 1867, was a member of the Board of Governors from that time, and for many years was honorary treasurer."—Hector.

Skey (1870–1898). Eighty-eight papers on chemistry. "With a natural bent for chemistry and diligent labour and study he had attained such a position as to be recognised as one of the world's foremost authorities in certain branches of the science."—Hector.

Cheeseman (1872–1923). Ninety-two papers on botany and geology. He reached New Zealand when eight years old and "his works must perforce be in the hands of all pursuing studies either with the flora or the vegetation and must be consulted daily."—Cockayne.

Fereday (1872–1898). Nineteen papers on entomology. A pioneering student in this branch of science in New Zealand.

Thomson, G. M. (1875–1927). Thirty-five papers on natural history. "A conscientious and enthusiastic naturalist, equally interested in problems of botany, in systematic zoology, and in economic zoology, and in the facts of acclimatisation."—W. B. Benham.

Bickerton (1875–1895). Twenty papers, mainly on astronomy. An exponent of the theories of cosmic and partial impact.

Broun (1876–1908). Eighteen papers on zoology. His work on Coleoptera was "a monument of the zeal and industry of an ardent naturalist."—Hector.

Hamilton (1879–1913). Fifty-five papers on natural history and anthropology. "An eminent student of Maori lore, a lover of nature, an earnest seeker after truth. Tupai te Ahorangi."—Hamilton Memorial Tablet.

Maskell (1879-1898). Thirty-nine papers on zoology. "Who took up the subject [of the scale insects] after the death of Signoret, and his name is now famous throughout the world as the best authority on it."—Ann. Rep. N.Z. Inst., 1899.

Petrie (1879–1926). Sixty-four papers on botany. "His name will always be revered as that of one of the great pioneers at a time when such were urgently needed in the domain of New Zealand field botany."—L. Cockayne.

Parker (1881–1894). Twenty-three papers on zoology. "For 18 years a member of the Council and an indefatigable supporter of the Institute."—J. Shand.

Chilton (1882–1929). Fifty-four papers on zoology. Who came to New Zealand as a boy. "No other life in the Dominion has ever been more generously given to the patient toil of learning and teaching, and yet has been so little in danger of becoming absorbed by them, to the exclusion of thought on the ends of learning and life."—G. M. Thomson.

Brown (1883–1903). Twenty papers on botany. "The most enthusiastic naturalist I ever met."—L. Cockayne.

Laing (1884–1940). Thirty-two papers on botany. "He claimed no high place for himself, but what he knew and thought he passed on eagerly to others."—H. H. Allan.

Hill (1887–1926). Forty-five papers, mainly on geology. "Hill had a most stimulating influence and did much to arouse and maintain interest in the study of natural science."

Hogben (1887–1918). Twenty-six papers on seismology. "Will be remembered for two things: as being one of the most eminent educationists the Dominion has produced, and as being the outstanding pioneer of seismology in the Southern Hemisphere."—G. M. Thomson.

Suter (1890–1919). Thirty-seven papers on zoology. "Patience, perseverence and concentration were his characteristics."—C. Hedley.

Best (1898–1923). Seventeen papers on anthropology. New Zealand born, and "her greatest student of Maori lore and culture." —Peter Buck.

Cockayne (1898–1933). Fifty-three papers on botany. "His was an open, challenging, enthusiastic spirit, consumed almost entirely by the desire to advance New Zealand's botanical knowledge."—R. M. Laing.

Thomson, J. A. (1906–1926). Fifteen papers on geology. "One of the most distinguished men of science New Zealand has produced."—J. S.

Of distinguished workers whose fame rests less upon matter appearing in the *Transactions*, but whose contributions we are glad to acknowledge may I mention Cowan, Dendy, McKay, S. P. Smith, Rutherford, Somerville, Tregear, Morgan, Tillyard, Guthrie-Smith, Hilgendorf? To many another I would fain pay tribute—our annals

are rich. Nor must we altogether forget those who achieved no special fame, did not come into the light of public notice, but who helped to build the edifice, the foundation stone of which was laid by Solander, the corner stones by Hector, Hutton and the other heroes of 1869, and which must go on building through the years to come. Of the servants of the Society and of science in the Dominion who are still with us I shall not speak. Some of them are before me now. Before me, too, are some of those who are still advancing to the peak of their achievement. Throughout the country there are ardent workers. May the example of the pioneers hearten us all to further the cause of science for humanity, to encourage those just entering on a path that may lead to no great monetary rewards, but to great contentment of soul.

A brief reference to famous overseas scientists who have contributed to our pages should not be omitted. Their names recall great achievements. The dates refer to their election as honorary members. J. Agardh (1900), F. von Mueller (1870), O. Finsch (1870), L. Lindsay (1871), J. E. Gray (1871), R. McLauchlan (1874), J. Stirton, S. Berggren (1876), D. Sharp (1877), J. Beneden (1888), A. Günther (1873), T. G. Bonney, A. Liversidge (1890), J. Tenison-Woods (1875), A. Reischek, C. von Ettingshausen (1888), H. von Jhering, C. Hedley (1894), A. de Quatrefages, G. Massee (1900), O. Klotz (1903), O. Beccari, W. M. Davis (1913), O. Wilckens (1936), C. Skottsberg (1938). Very substantial contributions, 51 papers, were made by E. Meyrick, who was elected an Honorary Member in 1907. "One of the most renowned workers on the microlepidoptera of the world."—G. V. Hudson.

So from Great Britain, Australia, the United States of America, Sweden, Germany, Austria, Belgium, France, Italy, and Brazil our pages have been enriched by papers from 11 zoologists, seven botanists, and six geologists of great repute, and by the paper on "Transpacific Longitudes" of O. Klotz.

Any student of the history of the New Zealand Institute and of the Royal Society will agree that we may be proud indeed of the work accomplished. This address is a review of but one aspect. No one conversant with the record and qualified to judge will dispute the claim that over 75 years our *Transactions* have contributed greatly to our store of knowledge and to the advancement of the Dominion. I think we can justly claim that in recent years the standard has been well maintained, though the range of subjects has decreased. This decrease should not receive over-emphasis. As I have pointed out, three sciences have dominated almost throughout. The *Transactions* have provided room for papers of basic interest and importance, often lacking in popular interest and therefore apt to be undervalued or unrecognised by the general public, and even by our legislators. Such research may appear remote from everyday affairs, but there are not wanting signs that our legislators and the general public are becoming more and more seized of the fact that these investigations may lie at the very base of our social structure, and on them depend in no mean measure the development of our resources, the furtherance of our industries, the welfare and health of the community.

We here have all been exercised in mind by the lack of sufficient funds fully to cope with the valuable work coming forward, and have been, temporarily one sincerely hopes, compelled to restrict the cost of individual papers. It will be our duty so to justify our claim for further financial assistance by putting our record and aims plainly before those whose duty it will be to evaluate them in terms of their worth to the Dominion, that substantial help may be forthcoming, and the work proceed.

We have to face the future, and play our proper part in the changing world with its new problems. It may be that as further journals come into being our *Transactions* may assume a somewhat different shape. It may prove our best course to provide avenues for the publication of the longer papers and bulletins that are beyond the scope of ordinary journals. We shall have to consider more fully, too, means of enlightening the public as to what our functions are, and of explaining to them what is being accomplished. It may not be our function to provide a popular journal, on the lines of *Endeavour,* which reminds us by its title and frontispiece that it was this ship that brought Solander and Banks to our shores. It will be our duty, however, to support any well-designed movement to enable the people of New Zealand to appreciate and value the work for science that is being done.

Ours is a great trust. May we see to it that the Royal Society maintains within itself "a sure principle of vitality, because it contains a sure principle of usefulness."

TRANSACTIONS

Vol. 74, Part I, pp. 1–23, 4 Text Figs., Plates 1–7.

A Contribution to the Life-History of the Brachiopod, *Terebratella inconspicua* Sowerby.*

By E. Percival,

Canterbury University College, Christchurch, New Zealand.

[*Read before the Canterbury Branch, April 3, 1943; received by the Editor, November 25, 1943; issued separately, June, 1944.*]

The knowledge of brachiopod development is so incomplete that any addition is still to be regarded as valuable, particularly when it covers a long range of embryological changes and metamorphosis. The present study provides a fairly continuous view of change from early segmentation to young adult life, and fills a gap which was inevitably left after the excellent work of Morse (6 and 7) and Conklin (1). The accounts of these two workers unfortunately do not provide a complete story of the growth to young adult life of *Terebratulina septentrionalis*. Conklin's report proceeds until the stage of the well-defined larva, but, by analogy with the present findings, stops while yet the mesoderm must undergo further elaboration. The fixed material with which he worked did not show the nature and extent of ciliation, but the details of development were generally very clearly elucidated, especially the origin of the mantle, which was transverse, so making the peduncle posterior in position. There is an uncertain amount of development between the last phase of Conklin's material and the first phase of Morse's. Further, Morse studied his material alive and only externally, so that much of what happened internally was not seen by him.

MacBride (5, p. 410) says, with reference to the fate of the blastopore (taken from Conklin's account): "Finally, this is closed, but a shallow pit is left, and in this same spot, at a later date, the invagination to form the stomodaeum arises. In this way a valuable landmark is created for the correlation of the region of the larva with reference to the adult organs." In the following account, it will be evident that it is not possible to foretell the relation between the site of the stomodaeum and that of the closed blastopore: in fact, the orientation of the Testicardines, as far as concerns *Terebratulina* and *Terebratella* is quite uncertain when considered in terms of previous work. It is possible to relate the arrangements of the young adult with those of larval and pre-larval life only by the following through of metamorphosis. This has been done in the present work, and results in a reconsideration of previous views on orientation: in short, the current terms of dorsal and ventral, as applied to the adult must be reversed, what was called dorsal is primarily ventral as it is related to the blastopore, and vice versa.

Conklin's account of the origin of the mesoderm of *Terebratulina* as an anterior outgrowth from the archenteron does not apply to *Terebratella*, where it is posterior. The mode of origin of the mouth and of the lophophore, as described by Morse, does not agree with present findings, or is so inadequately described as to make desirable

* Determined by Dr. R. S. Allan, to whom the writer is indebted.

further information. It must be kept in mind that Morse and Kowalewski (3) made their studies on whole specimens, alive, and that, having regard to the minute size of the material, their drawings and conclusions must always be considered of high rank.

Notes on the Ecology of *Terebratella inconspicua*.

Collections for the present purpose were made between tide-marks in Lyttelton Harbour, New Zealand, on the breastwork of a disused jetty at Governor's Bay, and on the inner face of the retaining wall of the Gladstone Wharf of the Inner Harbour, at Lyttelton. The population at the former site is small, but at the latter is dense and extensive. In both places the brachiopods occur up to about half tide mark, attached to stones and other solid objects, but hidden in such a way as not to be disturbed by currents. It seems that the water which passes over them is always gentle in its action, there being little more movement than that caused by the rise and fall of tide without lateral swirl. At the Inner Harbour, the animals are found on the downward faces of stones which are either heavy, or partly embedded, or deeply situated. The surfaces on which attachment is made are covered with a thin film of organic detritus, and there are indications that a fine suspension bathes the brachiopods and other associated filter feeders during the presence of sea water. This fine deposit indicates quiet conditions in the vicinity and gives support to the conclusion that the attachment of larvae and metamorphosis and early post-metamorphic life could proceed only in quiet circumstances. The very small larvae have been observed in the laboratory to swim chiefly near the substratum but also to rise so much as two inches towards the water surface. In late free life, after emergence from the parental mantle-cavity and before attachment, there was seen a temporary tendency to congregate towards the light, but later, after 20 to 30 hours of freedom, there was a movement towards the substratum over which the animals appeared to run, as though with the aid of legs. This movement was jerky and erratic, with the flat or slightly concave surface ventrally placed, the arched surface being dorsal. Rotation about the long axis ceased in these circumstances.

All the early life, prior to the short swimming period, is spent in the mantle cavity of the parent, although on one occasion unfertilised eggs were extruded on the floor of the dish containing the adult.

The running about over the substratum had nothing to do with feeding, since there is neither mouth nor gut at this stage, nor will there be for some time. It seems that the whole of embryonic, larval and a significant part of post-metamorphic life is maintained by means of the food reserve stored in the egg.

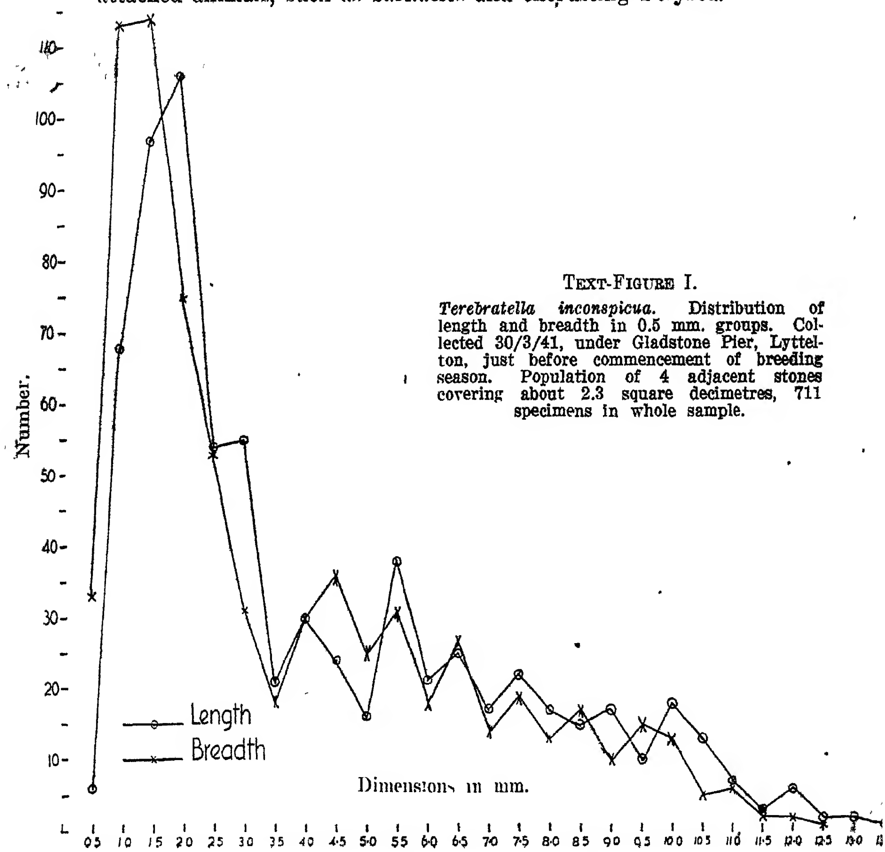
Attachment takes place in nature, in the Lyttelton collecting ground, in rather well-defined conditions, since this species of brachiopod has been rarely found mixed with any other animals of similar size. It occupies the most sheltered portion of a stone and is commonly surrounded by an abundant filibranch mollusc, *Hochstetteria meleagrina* Bernard*, which may slightly overlap the margin

* Determined by Mr. A. W. B. Powell, to whom the writer is indebted.

of the brachiopod area. The filibranch actively creeps over the substratum in its earlier benthic life, but lives decidedly outside the region of *Terebratella*. Associated with the brachiopod is commonly found, in autumn, the juvenile form of a species of *Sycon* as are also several small species of errant polychaetes and of Polyzoa.

The breeding season, in Lyttelton Harbour, has been determined as generally from early April to late May, with its greatest intensity during May. Early stages were found in two females taken in the last week of March, but, commonly, material collected at the end of March had not yet spawned. Specimens collected on June 6 were spent or immature. During three years, collections made at different dates in this part of the year established the breeding period. In early June no newly attached young were found on the collecting ground, but the youngest already showed some appreciable growth, addition to the shell margin being discernible.

Attachment at first is very weak, but later becomes firmer. How this strengthening comes about is not obvious, but, as those well know who have collected live brachiopods of this kind, there is practical fusion between peduncle and substratum as the animal grows. This, of course, is similar to what takes place with many attached animals, such as barnacles and encrusting Polyzoa.



TEXT-FIGURE I.

Terebratella inconspicua. Distribution of length and breadth in 0.5 mm. groups. Collected 30/3/41, under Gladstone Pier, Lyttelton, just before commencement of breeding season. Population of 4 adjacent stones covering about 2.3 square decimetres, 711 specimens in whole sample.

Very many newly attached larvae are to be found in slight recesses or behind slight ledges on the substratum. In the former case, death may ensue owing to lack of room for growth. It seems that very many young ones become thinned out in the first year, in part through overcrowding, in part through starvation, and in part for no apparent reason. Dead shells of juveniles less than one year old, or less than half a year old especially, were very common in wholesale collections which were picked from stones under the microscope.

An attempt was made to determine the structure of a population living in good circumstances—i.e., one showing a wide range of sizes and a high proportion of juveniles. 711 specimens were picked from four adjacent stones covering an area of about 2·3 square decimetres. They were measured along the greatest length and breadth. The measurements, collected in 0·5 mm. groups, are plotted in Text Fig. 1. The collection was made on March 30, 1941, just before the breeding season commenced, so that the youngest specimens would be nine months old at the most and the oldest of the previous year's brood would be hardly 12 months old. The gonads of the adults were nearly mature, but no female showed free eggs.

It will be noticed that the first of the peaks of the graph ranges between 0·5 mm. and 3·5 mm. with the maximum length round 2 mm. and the maximum breadth round 1·5 mm. A second broad crest, less definite than the first, lies between 3·5 mm. and 7 mm. long, a third, still less clear, between 7 mm. and 10·5 mm. long, leaving a fourth portion tailing off to a length of 13·5 mm. All this material was brownish, covered more or less densely with an encrustation, not even the smallest specimen showing the sharp, clear, glistening whiteness of new shells, but a sample collected on April 29, 1941, of 150 specimens, contained 18 clear, white small ones, obviously recently produced, of length ranging from 2·3 mm. to 3·8 mm., and three brown, encrusted specimens of lengths, 5·0 mm., 4·4 mm., and 3·3 mm. respectively. These three were, without doubt, of the 1940 year class, and stood out sharply from the other small specimens.

The measurements indicate that growth in Lyttelton Harbour is slow, and, if the plottings do in fact show four year classes, the life of the population is short. Nearly two-thirds of the population consists of the first year class, nearly one-quarter of the second year class, nearly one-seventh of the third year class, and nearly one-thirty-fourth of the fourth year class. What the conditions are elsewhere has not been determined. However, while the maximum length in Lyttelton has not been found greater than 13.5 mm., specimens from Foveaux Strait are decidedly longer. Six specimens in a sample of ten ranged in length from 18 mm. to 22 mm., with a similar range of breadth.

An attempt was made to examine growth in length by the measurement of growth-lines, but unsatisfactorily. There are many subsidiary lines, well-defined, commonly coincident on both valves and leading to confusion. It might be expected that growth checks would be recorded fairly concurrently by members of a closely settled population, but if the lines do include marks of growth checks, they occur very irregularly. However, it can be said that the results of growth-line measurement agree loosely with the subdivision of the

particular population into four year-classes ranging in length as follows:—

First year class	up to 3.5 mm.
Second year class	3.5 mm. to 7.0 mm.
Third year class	7.5 mm. to 10.5 mm.
Fourth year class	10.5 mm. to 13.5 mm.

THE EMBRYOLOGY OF *Terebratella.*

The genital products of the male are probably passed ultimately into the mantle cavity of the female where fertilisation normally takes place after the eggs have collected there from the ovaries. The word "normally" is used because, as has been mentioned, in only one case were eggs extruded from the mantle cavity on to the bottom of a dish, and because material used for study was obtained from the mantle cavity. The close association of individuals on stones would make easily possible the passage of sperms from male to female, and, the sex ratio of several samples totalling about 200 being about 1:1, there is a strong likelihood that the sexes are quite well mixed.

The eggs extruded on to the bottom of the dish were not fertilised and resembled unfertilised eggs taken from the mantle cavity.

Both eggs and early developmental stages were found applied to the inner surface of each mantle fold, not particularly associated with the lophophore. Although, later, ciliated stages swam freely in the water in a dish, there was no clear indication that free-swimming took place throughout the mantle cavity, except, perhaps, towards the time when the larvae should leave the parent. Later stages were more loosely packed than earlier and more easily passed into the surrounding water when the valves were prised apart.

The unfertilised egg, from the mantle cavity, is rather irregular in outline, often polygonal, sometimes ovoid, usually flattened, and generally having the appearance of being recently closely packed. The unreduced nucleus is large, about one-half the diameter of the cell, slightly eccentrically placed, circular in outline, and visible by its relative transparency, the egg contents being otherwise dense and opaque. In this early stage, there is on the surface a coat of closely-fitting flattened cells. After the assumption of the spherical form, no doubt through the absorption of water, the egg is seen to have from 20–30 cells round any meridian (Plate 1, Fig. 1). Turgidity and sphericity of the egg are quickly followed by the disintegration and loss of the investing layer, and the egg wall becomes exposed to the medium.

The mixing of teased ripe testes with unfertilised eggs was quickly followed by the disappearance of the translucence marking the position of the large nucleus. This suggests that reduction takes place after impregnation, but polar bodies have not been seen, either in these circumstances or on fertilised eggs taken from the parent. In five minutes after the mentioned mixing, there appeared a narrow clear zone immediately inside the follicular layer, very similar to a fertilisation membrane. In 1½ to 1¾ hours after the appearance of the "fertilisation membrane," the follicular layer began to break up and the egg to present a smooth, uniform shape. The diameter of the smooth, spherical egg, with follicle, was about 0·18 mm.

Conklin (*op. cit.*) described the cleavage in his *Terebratulina* material, but gave no information about the method of fertilisation or about the conditions in which the eggs developed. He mentioned that segmentaion was variable, from regular to very irregular. In the present study, early segmentation, after mixture of teased ripe testes and unfertilised eggs, was watched and was found to vary very much. Regular cleavage produced two, then four, equal blastomeres by the first two vertical clefts at right angles to each other. The third horizontal cleft gave eight equal blastomeres (Plate 1, Fig. 4), as determined by measurement, which is remarkable, since the unreduced nucleus was nearer one part of the egg surface than to any other. A differentiation into micromeres and macromeres would normally be expected, but this was not seen at any stage where individual cells could be recognised. The fourth cleavage was vertical and radial, producing a blastula of sixteen cells. An eighteen-hour blastula of 24 cells consisted of upper and lower quartettes separated by two octettes, all showing radial arrangement.

Irregular segmentation varied from slight size differences of blastomeres in early cleavage, to the budding of micromeres from a single, very large macromere. Regular segmentation proceeded to the blastula stage, when the material was killed and fixed, but the irregular segmentation was followed sooner or later by death. It is reasonable to conclude that regular, radial segmentation is normal in this animal. The heavy death-rate in irregular specimens was not found in nature. Survival in the mantle cavity was found at all times to be high, and observed early segmentation stages were regular, although simultaneous division of blastomeres often did not take place. The irregularity observed in the laboratory was regarded as due to the conditions of the experiment. Conklin (*op. cit.*, p. 46) thought that irregular segmentation might give rise to normal larvae by rapid division of macromeres; nothing comes out of the present study which would lend support to that suggestion.

As Conklin well showed in *Terebratulina*, in *Terebratella* gastrulation is by invagination. Late blastulae are immobile and show no recognisable difference between animal and vegetative poles (in the absence of polar bodies). The gastrula is first nearly spherical, then hemispherical with a flat blastoporal face. At first the blastopore is circular with diameter about one-third that of the body, but later undergoes change of shape, as will be noted later.

The gastrula early becomes ciliated, at first with no locomotion, then, later, with slow movement, usually blastoporal face downwards, but movement takes place when the abporal surface is down, indicating a general ciliation of the body surface.

After about 18 hours from gastrulation, the blastopore becomes narrow and slit-like, with a shallow groove running back from the pore; the body takes on a rather square outline in plan with a blunt, wedge shape seen from the side, the blunter, thicker end being anterior. The groove from the blastopore passes back

towards the thinner end in the middle line. During the change in shape is an alteration in the distribution of cilia (Plate 1, Figs. 5, 6, 7). Those over the blunt half remain, and when the wedge shape is clear, the narrower half loses the cilia, earlier from the dorsal, ventral and lateral surfaces, and later from the posterior end. Thus, a body is left with the blunt half only bearing cilia; this blunt half will form the anterior lobe, while the unciliated part will form the peduncle. Soon the right and left sides of the body become slightly concave, with a continued tendency for the posterior part to grow narrower than the anterior part. The blastopore becomes narrower posteriorly, and seems to be carried inward by a slight secondary invagination of the surrounding cells: this recess remains until after closure of the pore. The blastopore, in its recess, shortens and comes to lie in the middle of the ventral side of the anterior lobe, although the recess extends medially to the posterior end of the ventral surface (Plate 1, Fig. 9). It is not possible to decide whether or not the blastopore closes by the fusion of its sides, from behind forwards: there is nothing in sections to support a suggestion that closure is by concrescence, at least, during the earlier part. Final closure is brought about by the complete contraction of the margin, leaving a solid plug of epiblast cells leading to the hypoblast. During the narrowing and closure of the blastopore, an apical tuft of long cilia appears in the middle of the anterior end (Plate 1, Fig. 7).

The lack of obvious difference between any two parts of the blastula made impossible the determination of the animal pole, in the absence of polar bodies. Conklin was unable to satisfy himself about the position of this part in the differentiating embryo. He pointed out the fact that the blastoporal surface is ventral in *Terebratulina,* as it is in *Terebratella,* and we are faced with the difficulty of deciding whether or not the apical tuft of cilia is primarily apical in being produced by cells derived from the animal pole of the egg, as is so very often the case, or is secondarily apical only because it is at the anterior end of the long axis in locomotion, not coinciding with the animal pole which may be somewhere dorsally. Superficially, the apical tuft is derived from a part of the equatorial region of the blastula, if gastrulation proceeds in a manner similar to that—e.g., of *Amphioxus*, namely, through the invagination of the vegetative region. Nothing comes out of the present work satisfactorily to show the relation between the axes of the fertilised egg, the blastula and the larva.

The speed of locomotion gradually increases, the body gliding over the substratum (the bottom of a dish), the blastoporal face being usually downward. The bodily shape markedly changes so that a large downward bulge forms on the anterior end (Plate 2, Fig. 10). This is associated with the formation of a long, broad slope downwards and forwards over the anterior, dorsal half: the apical tuft continues to occupy a central position. Thus, from the side, the body has two fairly well-defined regions, the thickened, ciliated anterior end, with its downward bulge and its antero-dorsal slope, and the unciliated, more slender, posterior part which gives rise to the peduncle.

Posteriorly, bordering the ciliated region, a dorsal constriction marks the front margin of the mantle rudiment which arises as a low dorsal, transverse ridge and extends down each side finally on to the ventral surface (Plate 2, Figs. 11, 12, 13), in the manner described by Conklin in *Terebratulina*. The two ventral ends come to be one on each side of the hind part of the blastoporal recess, but soon this goes and the mantle fold completely surrounds the body. The fold is slightly higher dorsally and laterally than ventrally, while the blastoporal vestige is present on the ventral face of the anterior lobe. Locomotion is now in the form of a slow, sinistral revolution about the long axis and the body can be raised slightly from the substratum.

The mantle rudiment grows backward as a sheath enclosing a continually narrowing peduncular rudiment, until, in the end, only the tip of the peduncle remains visible (Plates 2 and 3; Figs. 15, 16, 17). During the elaboration of the mantle and the stalk, the latter changes from being a thick, squat appendage to a slender, tapering structure. Earlier, the cross section is a rather large, rough parallelogram; later, it is a small circle. The anterior lobe changes in form from being a somewhat broad, transverse body, sloping downwards and forwards, to a more elongated, conical structure still having the tip (with its apical tuft) tending towards the mid-ventral line.

In this way the dorsal arch of the body remains, and the orientation can be determined well past the time of the disappearance of the blastopore: indeed, the dorsally arched outline and the ventrally slightly concave, or flat, outline, persist until metamorphosis and serve as valuable data of reference in the work of orientating the adult.

When the conical form of the anterior lobe is finally established, the apical tuft of cilia is already lost (Plate 3, Fig. 16). This takes place some time before the larvae leave the parental mantle-cavity, and the later life, up to the normal time of exit from the brood chamber, is spent in the completion of the mantle fold rudiment and in the elaboration of the mesoblast, which, however, can be seen satisfactorily only by means of sections.

When larvae (Plate 3, Fig. 17) left the parent in a dish in the laboratory, they swam high, near the water surface, about 1¾ inch up, and towards the light. Locomotion at this stage is ciliary and vigorous, with sinistral rotation about the long axis. The anterior lobe is still the only ciliated part, the mantle and peduncle never having been ciliated since they began to differentiate. Although the late larva appears to have cilia of two lengths, a well-defined broad band of long ones round the base of the anterior lobe and apparently much shorter cilia covering the rest of the lobe, all the cilia were of the same length when larvae were freshly killed. The difference in appearance in life may be due to the form of the ciliary beat.

The normally free swimming larva is about 0·2 mm. in length and about 0·14 mm. broad at the widest part, through the base of the mantle rudiment. It has about 60 small pigment spots, probably eyespots, round the posterior margin of the anterior lobe, and is somewhat positively phototactic. Four tufts of setae have been for some time on the mantle edge, roughly equidistant from each other, and projecting backward. Conklin (*op. cit.*, Plate 9, Figs. 56 and 57)

figures what he calls setae sacs, indentations on the inner face of the larval mantle, which, if they indeed carried setae, would bring them well on the outer face after reversal. In *Terebratella,* the pits in which the setae grow, if pits there be, are so small as not to have been seen in sections. The so-called setae sacs of Conklin's figures resemble closely sections of the fold formed when the mantle has already begun to reverse.

Metamorphosis: External Changes.

The shortest observed period of free-swimming life of the mature larva was 24 hours, when attachment occurred. One batch all became fixed by about 30 hours, but others remained swimming for several days, most of them ultimately disappearing. How long active, free locomotion takes place in nature is not known. As the most successful spatting took place within a short period (24–30 hours) and the least successful in a long one, it is probable that, in nature, the free swimming life is rather short, perhaps about 30 hours.

The larvae become loosely gummed to the substratum by means of the tip of the peduncle (Plate 3, Fig. 18). An accumulation of fine detritus stuck to mucus forms round the base—the larger the mass the longer the attachment. Attached larvae were observed for many hours in the laboratory to sit with the mantle slightly dilating and contracting, while the anterior lobe quivered almost continuously, undergoing spasmodic violent contractions and tiltings, all the time tending to become broad and squat. There were generally striking evidences of muscularity and the cilia actively vibrated, particularly those forming the well-marked basal band.

The actual process of mantle reversal has not been observed. It must be very quick because numerous specimens kept in the laboratory and collected in the field were found in various stages of rearrangement after reversal, and only one which had a form suggesting the beginning, but not one caught in the act, with the mantle partly reversed (Plates 3 and 4; Figs. 18, 19, 20). Sections and whole mounts indicate that the mantle begins at the base to reverse, so that a circular fold is formed round the base of the anterior lobe. which slides upwards, the lower edge being the last portion to pass up. This kind of reversion is similar to that called pleurecbolic eversion and figured in Pelseneer (8, Fig. 72).

The anterior lobe is not immediately totally enclosed at reversal. Many specimens show the lobe unsheathed to varying extents, and as the mantle edge moves upwards it changes from circular outline to the elongated border of an ultimate slit (Plate 4, Figs. 23, 24, 25). The body—i.e., anterior lobe, contained by the mantle, becomes flattened and broadened, the slit-like mantle-opening gradually swallowing the anterior lobe on which, in life, the cilia may still be observed to move. The opening is about one-third the circumference, and bears the larval setae on its edge rather scattered, no longer in tufts (Plate 4, Fig. 22).

During the later period of enclosure, when dorsoventral flattening has taken place, the outer surface of the mantle becomes

glistening white and smooth. The shape is no longer plastic, and there is clear evidence of the formation of a hard shell. Acid fixatives lead to the formation of a space between the mantle ectoderm and a thin outer cuticle which presumably lies outside the shell as a periostracum, and the conclusion is that the shell lay in the space. It seems, therefore, that the mantle produces first the thin cuticular shell followed by the calcareous.

During this early period the animal sits upright on the stalk, but soon the body tilts on the joint with the stalk (Plate 4, Figs 24, 25). Even before this there is evidence that the two flat sides are unequal in length, one valve projecting backwards more than the other, and this dissimilarity increasing, brings about a more pronounced tilt towards the other side. At rest, the animals stand as erectly as possible, but quickly bend downwards, closing the valves when disturbed by touch or shock.

The area of junction of mantle and stalk is at first circular in outline but becomes transversely elongated through the dorsoventral flattening mentioned above, and tapers narrowly towards the two ends. It later becomes modified in form as the base of the larger valve projects more and more backwards, causing the peduncle to project sideways and backwards instead of backwards. By the time of appearance of the stomodaeal rudiment, the peduncle has taken up almost its final relation with the body.

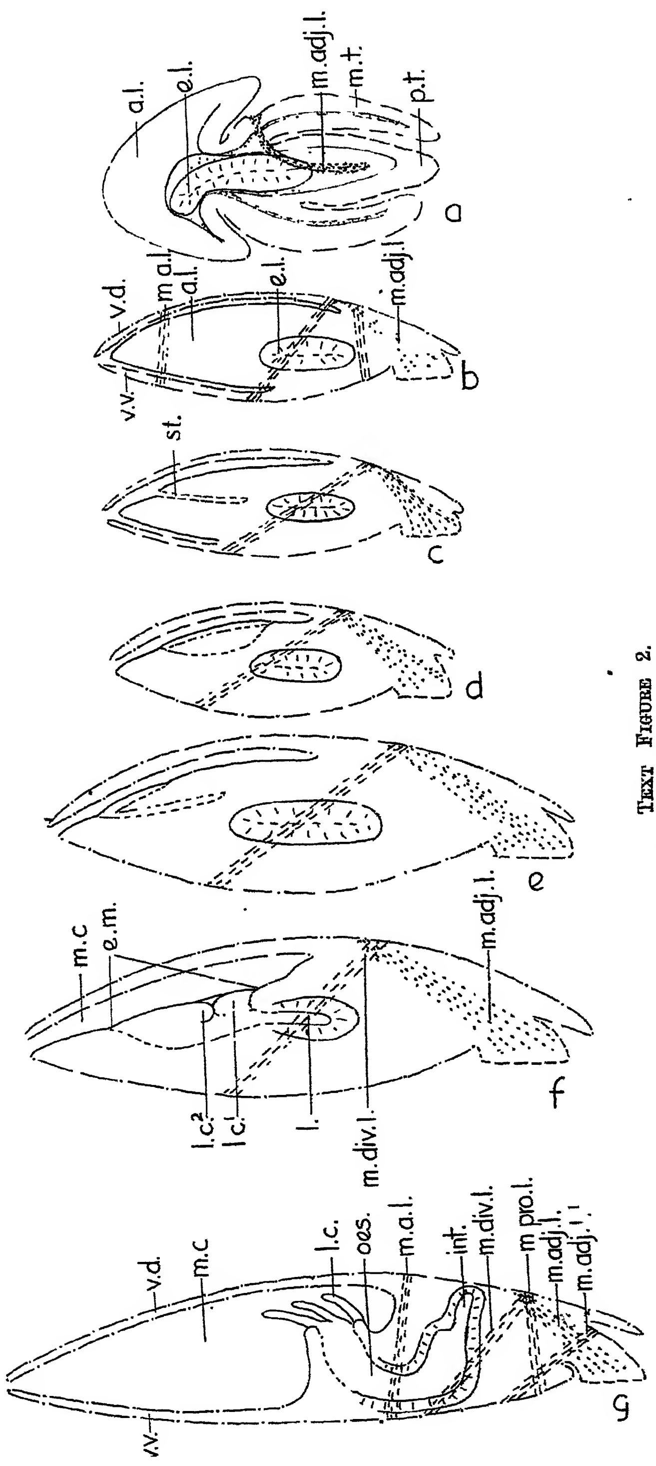
The shell grows obviously by addition to length and width at the mantle edge. In about three weeks after attachment an increase of about half the original length had occurred in laboratory grown specimens.

As has been mentioned by other workers, the larval setae disappear and are replaced by others which sit in deep pits on the mantle edge.

In the first few days after mantle reversal a great change takes place in the form and arrangement of the anterior lobe. At first, it is a strawberry-shaped mass having a broadly constricted connexion with the mantle (Plate 4, Figs. 23, 24, 25), and the mantle cavity may be described as a thimble-shaped space lying between mantle and lobe. During the period of flattening, a profound change passes over the apical lobe leading to the elaboration of mouth and lophophore, as well as enabling the development of gut, coelom and other adult structures.

It will save some description if it is stated here that the large valve is dorsal and the small valve ventral. This is the direct opposite of what has been accepted and the evidence on which the statement is based will be considered later.

Thus, we have at first an apical lobe contained in a mantle cavity which may be uniformly deep all round or slightly shallower on the ventral side than on the dorsal. As flattening proceeds, the ventral side of the cavity decreases in depth, more rapidly laterally than in the mid ventral line, so that the ventral surface of the apical lobe shortens until final disappearance as a recognisable layer. The lobe flattens and shortens until it is a layer lying on the inside of the smaller, ventral valve and replacing the ventral mantle lining: the surface faces upwards. This surface is



TEXT FIGURE 2.

Diagrammatic representation of transformation from larva to young adult, showing elaboration of anterior lobe and gut, and relation between dorsal valve and, dorsal adjustor muscle. From left side. Muscles shown as they have been observed in sections. For interpretation of abbreviations see page 23.

formed from the surface of the apical lobe (there is no obvious reason to think otherwise), so it may be regarded as having in its make-up dorsal, lateral and ventral elements, its anterior border immediately inside the ventral valve edge being the advanced, originally innermost, ventral part of the mantle at the junction between it and apical lobe (Text Fig. 2d).

On the remodelled, flattened apical lobe appears the rudiment of the stomadaeum (Plate 5, Fig. 26).

The earliest position of the stomodaeal invagination which has been observed was dorsally, immediately behind the tip of the apical lobe before the latter was completely enclosed by the reversed mantle. The invagination is at first a fine pit passing backwards and ventrally in the middle line. Its fine opening elongates backwards forming a thin slit and the stomodaeum as a whole is carried backwards with the changing shape of the apical lobe. The first observed appearance of the stomodaeum showed that the ventral portion of the mantle cavity was still large, but was undergoing reduction (Text Fig. 2c). At this period, the thick dense anterior lobe prevents the stomodaeal rudiment from being seen, but later, when the lobe becomes flatter and thinner, the pit becomes obvious in live specimens as a small median, transparent mark. It grows backwards towards a small gastric vesicle which is formed by the opening up of the previously closed, solid endoderm. When the two become confluent, the mouth begins to broaden and its edge proceeds to give rise to the filaments of the lophophore (Text Fig. 2f).

The matter of the origin of the mouth provides a problem which does not at present seem soluble. The blastopore closes ultimately without trace on the mid-ventral side of the apical lobe. This latter becomes reshaped into a flattened area on the inside of the ventral mantle wall. The reshaping ultimately brings the ventral face of the apical lobe into apposition with the dorsal mantle wall and in the same general plane as the originally dorsal face. During the reshaping, the stomodaeum early makes its appearance, but it has not been seen on the ventral side.

If the stomodaeum arises on the site of the closed blastopore, it must be morphologically ventral and must move round with the reshaping anterior lobe until it assumes a secondary dorsal aspect. If it does not arise on the site of the closed blastopore, there is nothing at present seen which enables a satisfactory conclusion about its first position on the apical lobe. Having regard to the very great rearrangement of material in the apical lobe, there is nothing inherently impossible in the conclusion that the stomodaeal invagination occupies the site of the closed blastopore and migrates from a primary ventral position to a secondary dorsal one.

With the appearance of the mouth, stomodaeum and stomach, the main outlines of metamorphosis may be said to have been laid down. A small, very simple, brachiopod is formed, with peduncle, peduncular area, unequal valves and elementary gut. Later changes, as observed, consist chiefly of the elaboration of these structures along with the further development of the coelom. Addition is made to the free edge of each valve, so that it becomes longer and

wider, and the body as a whole, through growth, becomes relatively thinner. As yet there is no sign of the calcified structure known as the loop, supporting the lophophore.

The Growth of the Lophophore.

When the stomodaeum has established open connexion with the stomach, the posterior margin of the widening mouth proceeds to give rise to two papillae, one on each side of the mid-line, the rudiments of the first two lophophoral filaments (Plate 5, Fig. 27). While these are still blunt and broad, two more appear, right and left anteriorly adjacent to the first two (Plate 5, Fig. 28). All four elongate towards the centre of the mouth opening. The fifth and sixth usually do not appear simultaneously, the sixth being slightly later than the fifth (Plate 5, Fig. 29). This succession has been observed more often than not (Plates 5 and 6, Figs. 30, 31, 32); thus, at six, ten, and twelve filaments, the sixth, tenth, and twelfth were each smaller than the fifth, ninth and eleventh.

Addition to the number of filaments and increase in width of the mouth proceed simultaneously, and along with increase in size of the animal: the lengths of the above-mentioned specimens were relatively, six filaments — 1, ten filaments — 1·5, twelve filaments —2·3.

In early summer (November and December), at a time when eight pairs of filaments are formed, there is a rapid extension of the anterior border of the mouth, between the latest filaments, without a corresponding increase in the diameter of the opening. The extra margin is accommodated by its bending inward so as partially to close the mouth by forming a crescentic slit with filaments only on the lateral and posterior border: the anterior invaginated border is always devoid of filaments, no matter how complicatedly folded the mouth becomes, and the addition of new filaments is at the end of each horn of the original crescent distally to those already formed and alternately on each side as described (Plate 6, Fig. 32).

The change in the shape of the mouth from a circle to an elongated slit makes possible an increase in the number of filaments and in food intake capacity without any other great increase in the size of the animal.

Morse (7, Plate 9, Figs. 90 and 91) describes and figures as tentacles or cirri two small bulges placed anterolaterally on the body of what must have been a very young adult of *Terebratulina septentrionalis*, while a pore between them is labelled as mouth. From the present account, it is difficult to reconcile what happens in *Terebratella* with what is reported about *Terebratulina*, especially as Morse's Fig. 94 in the above named paper, agrees more with what is given in this account of the origin of the mouth.

Internal Changes.

The unfertilised egg shows in section when stained with iron haematoxylin and eosin, or Erlich's haematoxylin, a dense peripheral layer of granules similar to basal granules of cilia. During the formation of the blastula, the granular layer becomes modified in its distribution, concentrated on the outer side of each cell, making ultimately a blastula having a peripheral layer of granules in the cells

while the rest of the cells contains none. At gastrulation, the granules disappear from the endoderm cells, there being a sharp discontinuity at the blastopore between endoderm and ectoderm. However, the ectoderm cells show a marked eosinophilous zone distal to the nuclei, and this continues into the endoderm, but not into the cells of the early enterocoelic pouch from which will form the mesoderm (Plate 7, Fig. 33).

The blastula shows no obvious differences in cell size between one part and another either in early stages or in late. Conklin's account of blastula formation agrees, in the main, with what has been found here.

The gastrula, in section, is similar to that described by Conklin, the blastocoele being obliterated. However, the formation of the enterocoelic pouch, from which the mesoderm arises, is strikingly different from that described by Conklin. He shows the pouch as an anterior outgrowth from the archenteron, formed originally by a downgrowth, from the roof, of a transverse wall one cell thick. In the present case, the enterocoelic pouch is a *posterior* outgrowth from the archenteron, initiated also by a downgrowth from the roof one cell thick (Plate 7, Fig. 33). Here, the young animal has been oriented by means of its direction of locomotion—there is no doubt about the position of the enterocoelic outgrowth. In Conklin's case, the material was already preserved and he had no opportunity to see live material. Before it is concluded that *Terebratella* and *Terebratulina* differ fundamentally in this respect, it would be advantageous to have *Terebratulina* re-examined.

The development of the mesoderm here has been followed step by step from the appearance of the early outgrowth from the archenteron. The larger anterior sac becomes the larval enteron, and opens outward through the blastopore. At the time when the single mesodermal outgrowth is formed, the gastrula has changed in shape to the blunt wedge shape when seen from the side and slightly so from the plan: the tapering part contains the mesodermal rudiment (Plate 1, Fig. 5).

The mesodermal sac now gives off laterally two forwardly growing horns which push between the endoderm and the ectoderm. The anterior ends of the horns are solid for some time and the coelom extends forwards a little later. At this time the lateral coeloms are continuous with each other and with the enteron (Plates 6 and 7, Figs. 34, 35).

As the wedge shape becomes more sharply defined, the coelomic sacs become broader anteriorly and are cut off from each other and the enteron. The enteron becomes relatively short and separates the coelomic sacs in the blunt, thick part of the body, while posteriorly the sacs lie apposed in the middle line. It seems that the changing form of the body, particularly, for this purpose, from the completed gastrula onwards, is largely the expression of varying relations between coelomic sacs and enteric sac.

The closure of the blastopore proceeds while the coelomic sacs are being formed, but its position is observable in sections by means of a plug of epiblast leading into the lower wall of the enteron. When the transverse ridge, which is the mantle rudiment, has ex-

tended to the ventral side, the coelomic sacs have divided each into an anterior and a posterior half (Plate 7, Figs. 36, 37), the former lying in that part forming the mantle rudiment and the anterior lobe, the latter lying in the peduncle. The peduncular sacs are apposed in the mid-line and their lumina are slight and for a time continuous dorsally with each other, while the anterior sacs are separated by the enteron, their cavities are rather large, and they extend quickly laterally and somewhat dorsally into the mantle rudiment. It seems that the mantle ectoderm forms an outward fold which is followed by an enlargement of the anterior coelom, since dorsally, while there is a mantle fold of ectoderm, it contains no mesoderm for the time being. All the coeloms contain a coagulable fluid.

When the mantle fold has encircled the body and the coeloms have divided, there is readily seen between the fore end of the enteron and the apical ectoderm a mass of cells, somewhat loosely arranged, agreeing in character with what Conklin described in *Terebratulina* as mesenchyme It is distinctly outside the coelomic wall, the irregular spaces within having no connexion with the coeloms.

With the further growth of the larva, the coelomic spaces become reduced, this being well marked in the anterior lobe, where sacs containing fluid become solid masses of cells. The mesoderm so formed extends into the sides of the mantle fold, but, for the time being, not into the dorso- and ventro-median portions. This may account for the attachment to the basal dorso-lateral mantle fold of the anterior ends of the two adjustor muscles which are the first to become defined and are formed each from a peduncular mesodermal mass (Plate 7, Fig. 39). These two masses have had their antero-dorsal ends in close apposition to the ectoderm. The anterior mesoderm, that is, of the mantle, later surrounds the dorsal ends of these two adjustor muscles.

Later, the whole mantle is provided with a middle mesodermal layer, but the manner in which this comes about has not been observed. In the early period, the mesodermal cells extending through the mantle are rather scanty and scattered between the ectodermal layers, but after the metamorphosis the mantle has a well-developed mesoderm throughout.

As the larva ages, the anterior mesoderm becomes more solid and homogeneous in appearance, but after metamorphosis there reappear left and right coelomic spaces laterally to the oesophagus and in front of the stomach. This reappearance was observed in sections at the stage of four pairs of lophophoral cirri, when the gastric diverticula were seen as the merest antero-lateral angulations of the stomach.

The two anterior coeloms, at this stage of eight cirri, are separated by very broad, dorsal mesenteries which are so low that the endoderm is dorsally and ventrally in contact with the ectoderm. Laterally and posteriorly to the stomach there is yet no clear coelom, but the musculature traverses an extensive space which has no obvious epithelial lining.

The disappearance and reappearance of the coelomic spaces are roughly parallel to the changes in the endodermal arrangement,

After the separation of the enterocoelic sacs, the enteron lies in an anterior position, the coeloms, as already stated, lying apposed posteriorly. The enteron decreases in size until, towards the end of free swimming life, its cavity has disappeared and there remains a solid rod of endoderm which anteriorly has a downward curve toward the ventral ectoderm of the anterior lobe. This solid endoderm remains throughout the metamorphosis until, later during the remodelling of the anterior lobe, its cavity reappears and opens out through the stomodaeum.

The Gastric Diverticula.

The earliest trace of the paired outgrowths, to form the so-called liver or hepatic caeca, was seen when the fourth pair of lophophoral cirri appeared. Two specimens, approximately five months old, reared in the laboratory, showed the earliest traces, when, at the same time the adult coeloms were appearing. There was a slight size difference in their fourth pair of cirri as there was in their diverticular rudiments. Specimens with five pairs of filaments show the outgrowths projecting slightly forwards. With further growth, the caeca extend somewhat in parallel, pushing into the coeloms, while at the same time their forward ends bend slightly inwards. They lie parallel to the oesophagus and are set out sharply from the stomach (Plates 5 and 6, Figs. 31, 32).

With the appearance of sixteen pairs of lophophoral filaments the diverticula begin to show signs of branching, three slight prominences appearing at the free end of each (Plate 7, Fig. 38a). These extend as finger-like sacs which then divide and are further increased by other outgrowths. At the same time, there was always seen a single outgrowth, postero-laterally from the angle alongside the place of origin of the primary diverticulum (Plate 7, Fig. 38c).

At the stage of three pairs of cirri, the intestinal caecum makes its first apparance as an outgrowth on the dorsal side of the enteron. Its subsequent growth calls for no comment, except that the end of the sac early comes into contact with the dorsal body wall.

The Orientation of Pre- and Post-metamorphic Forms.

Conklin (*op. cit.*) showed that the mantle is a dorso-ventral growth, dividing the posterior peduncle from the anterior lobe, and decided that " the valves which are formed by the mantle folds are dorsal and ventral, while the opening of the valves is anterior " (p. 61). Students of Brachiopoda—e.g., Schuchert and Cooper (9, p. 8) name the two valves dorsal and ventral, and seem to assume that the parts so arbitrarily named coincide with larval dorsum and ventrum. Conklin nowhere provides information which satisfactorily links the larval and adult dorsal and ventral surfaces, except that in his Figures 35, 61 and 62 he shows patches of cells which he interprets as rudiments of ventral sense plate and suboesophageal ganglion. This interpretation must have been based on an assumption that the parts did in fact pass over to the young adult and form portions of the nervous system, which could not be known since he was apparently unaware of the process of metamorphosis of *Terebratella* apart from what was provided by Morse's work. Morse's results give no clue to the relation between the fine structures of larva and adult.

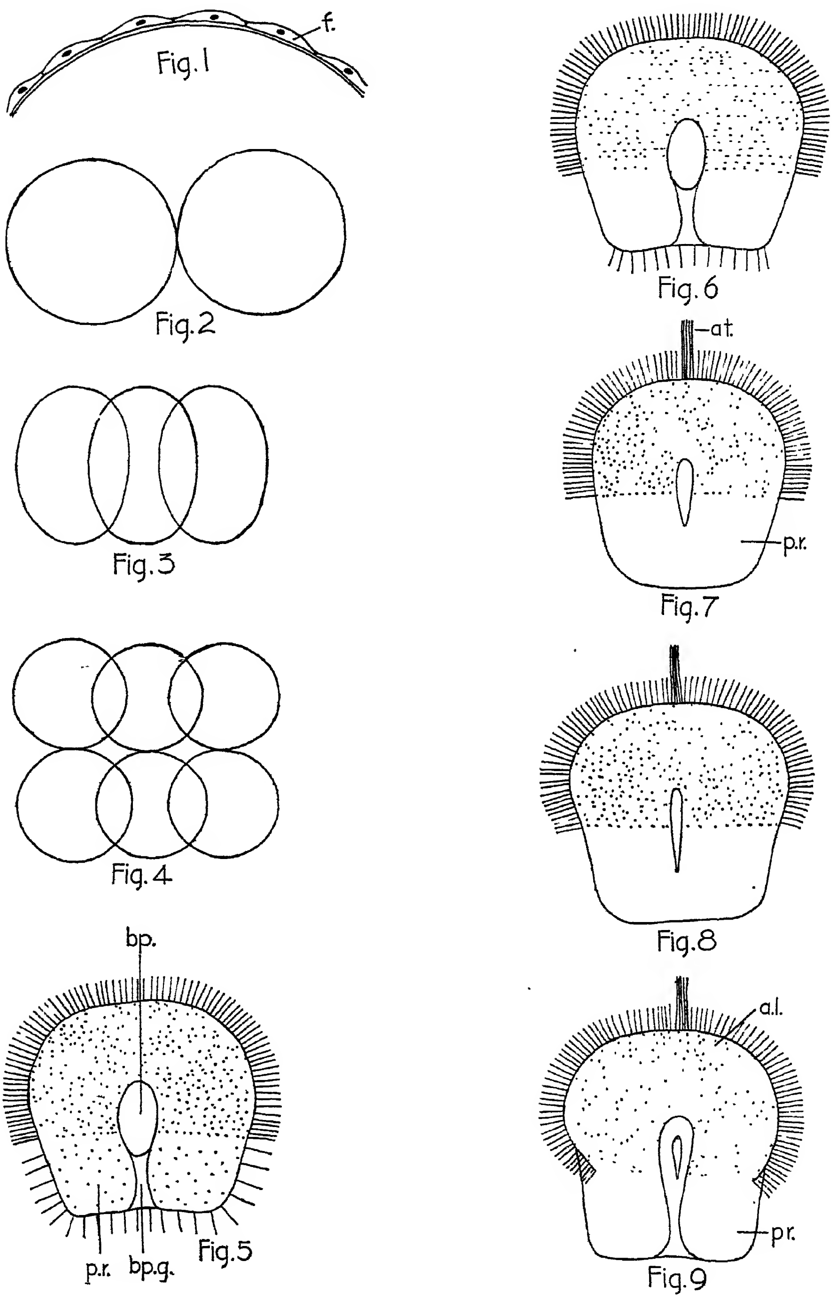


FIG. 1.—Optical section through part of equator of egg showing follicle cells.
FIGS. 2, 3, 4.—First, second and third cleavages.
FIGS. 5, 6.—Late gastrula, showing disappearance of posterior cilia, differentiation into regions of anterior lobe and mantle and stalk, and appearance of ventral groove from blastopore. Live material.
FIGS. 7, 8.—Complete loss of posterior cilia; appearance of apical cilia. Live material.
FIG. 9.—Differentiation of anterior lobe, from blastoporal face. Live material.

All figures based on camera lucida drawings.

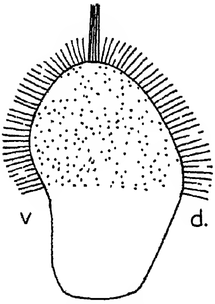


Fig. 10

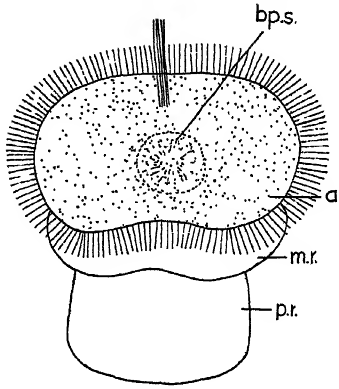


Fig. 11

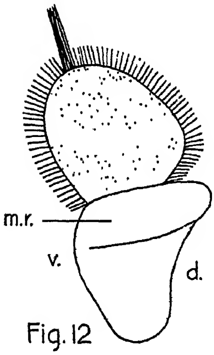


Fig. 12

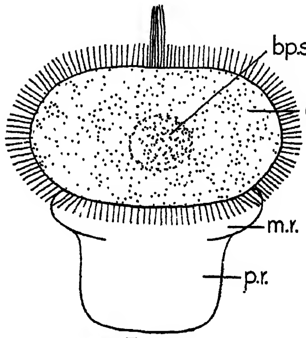


Fig. 13

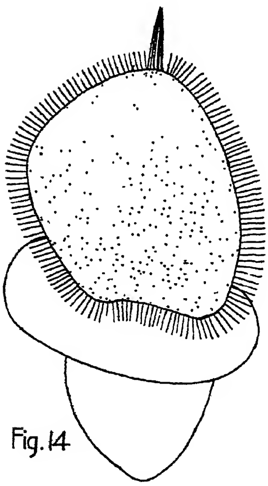


Fig. 14

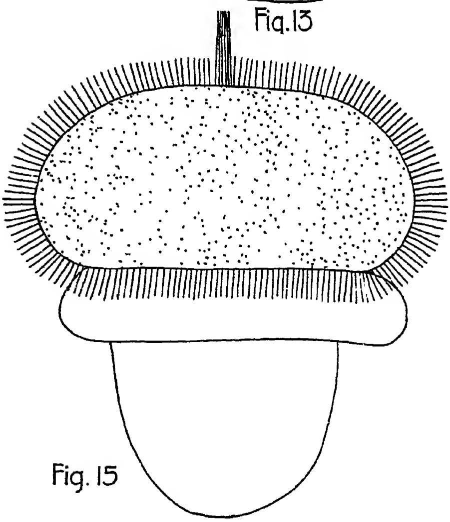
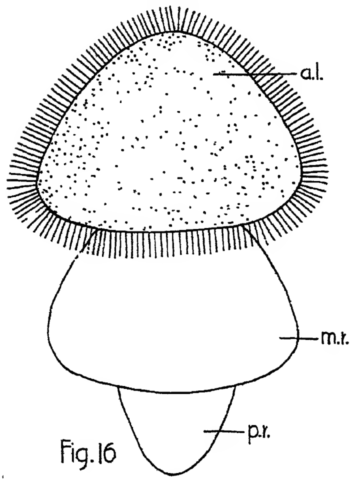
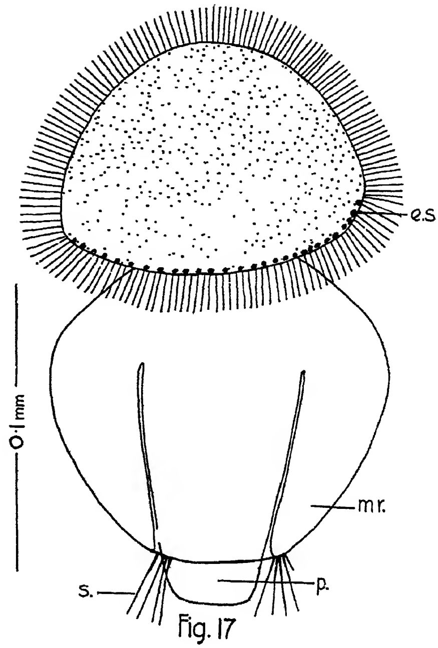


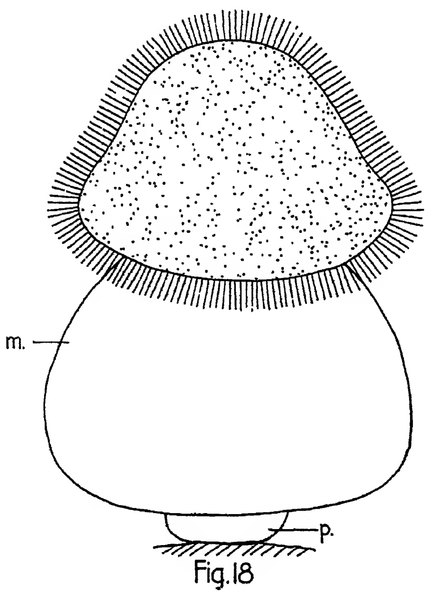
Fig. 15

FIG. 10.—Differentiation of anterior lobe, from left side. Live material.
FIGS. 11, 12.—Closure of blastopore, appearance of mantle rudiment and of rudiment of peduncle. Fig. 11 from dorsal side (blastoporal site seen by transparency), Fig. 12 from left side. Based on live material and whole mounts.
FIG. 13.—As Fig. 11, from ventral side. Live material.
FIG. 14.—Later stage with enlarging mantle fold, and more slender peduncle. Live material, lateral view.
FIG. 15.—As Fig. 14, dorsal view.

All figures based on camera lucida drawings.







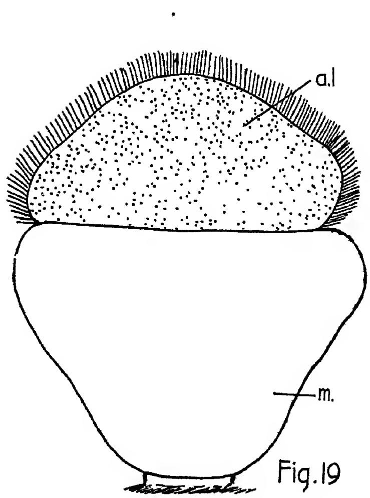


FIG. 16.—Older larva, with longer mantle fold and more slender peduncle. Apical tuft absent. Live material.
FIG. 17.—Mature larva on emergence from parental mantle cavity, with eyespots and setae. Based on live material and whole mounts.
FIG. 18.—After two hours' attachment. Live material.
FIG. 19.—After attachment; mantle beginning to reverse. Live material.

All figures based on camera lucida drawings.

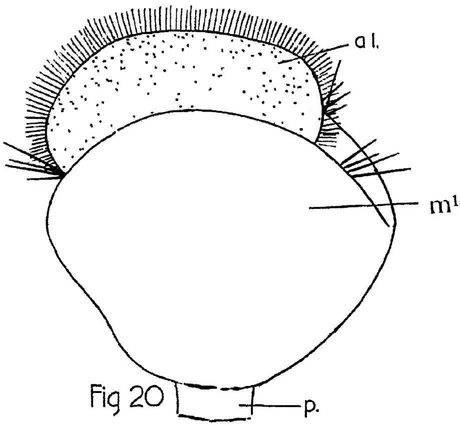


Fig 20

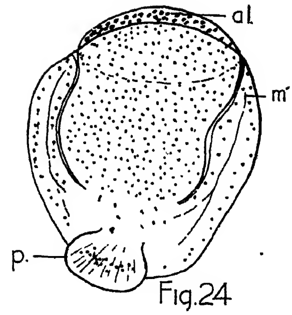


Fig.24

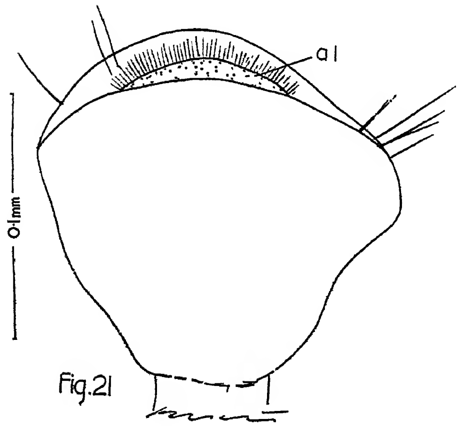


Fig.21

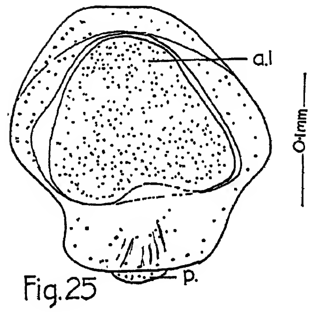


Fig.25

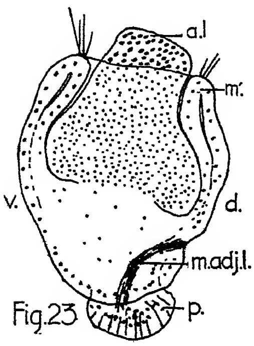


Fig.23

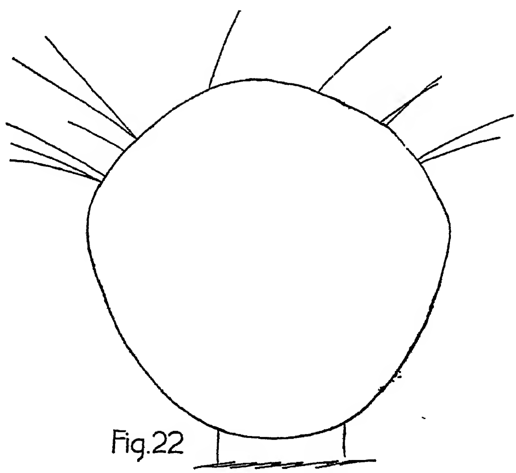


Fig.22

Fig. 20.—Shortly after mantle reversal, partial enclosure of anterior lobe. Live material.
Figs. 21, 22.—Enclosure of anterior lobe, Fig. 22 with early calcified shell. Live material.
Figs. 23, 24, 25.—As 20, 21, 22, Fig. 23 showing left pedicle adjustor muscle.
Fig. 24 ventral side. Fig. 25 dorsal side. Whole mounts.

All figures based on camera lucida drawings.

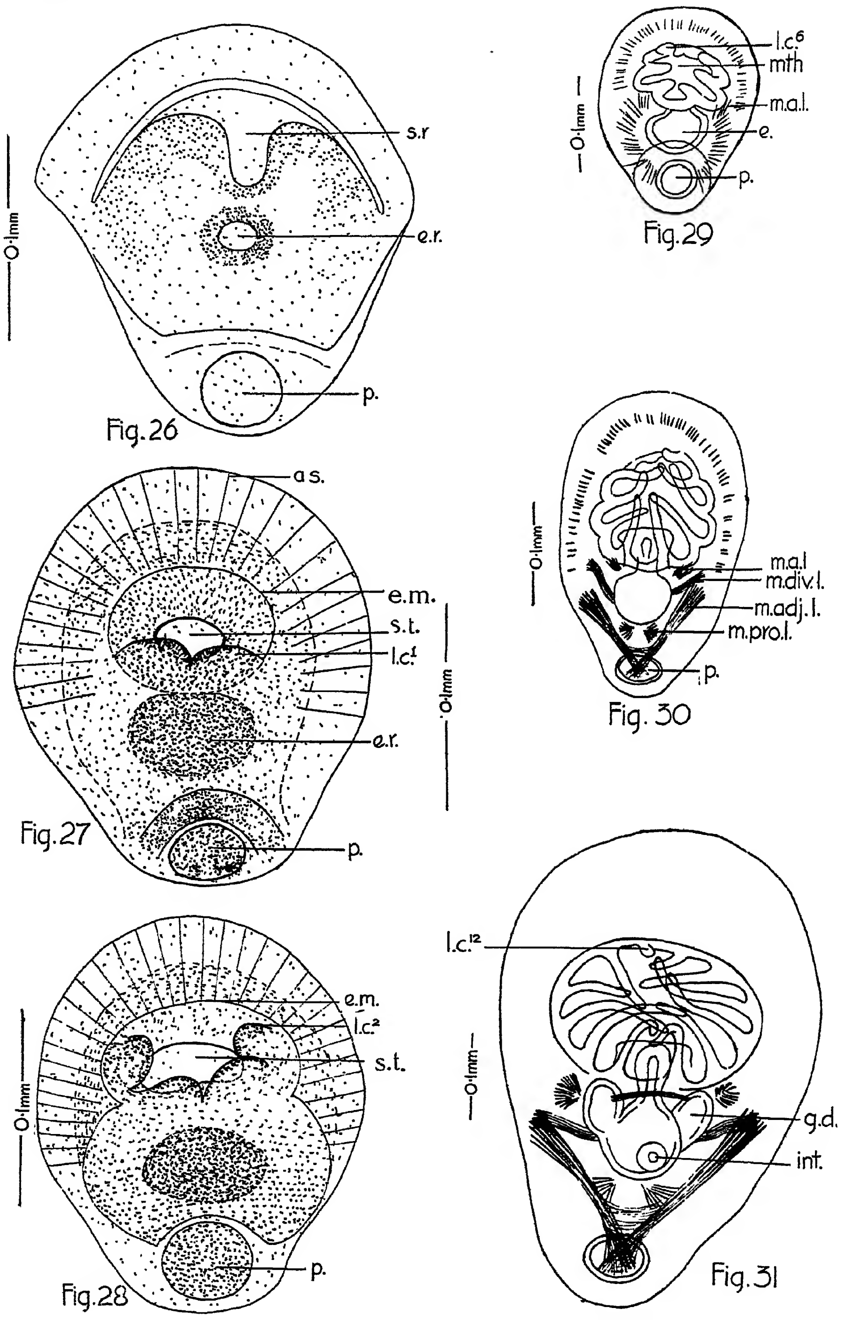
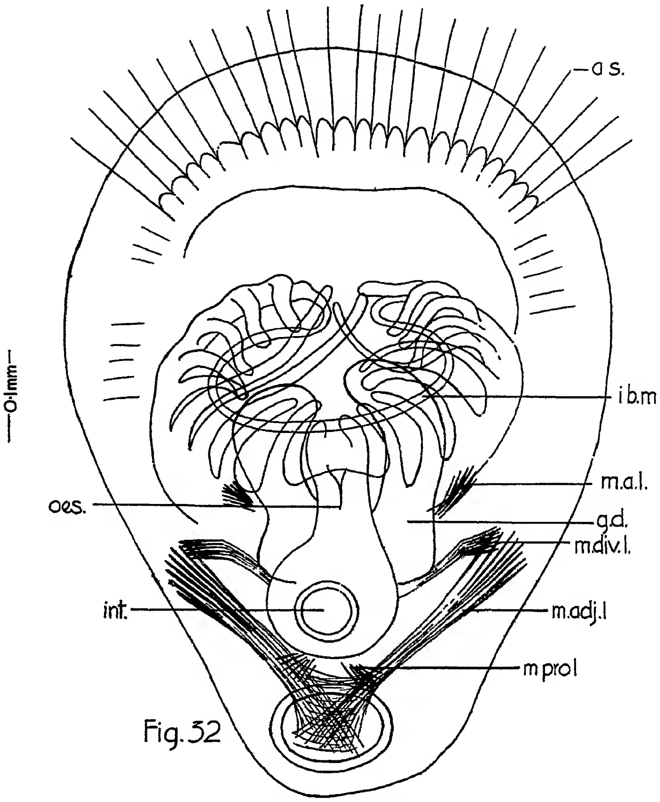


Fig. 26.—Early appearance of stomodaeal invagination, before its union with rudimentary enteron. Ventral side. Whole mount.
Fig. 27.—Rudiments of first pair of lophophoral cirri. Ventral side. Whole mount.
Fig. 28.—Rudiments of first two pairs of lophophoral cirri. Ventral side. Whole mount.
Fig. 29.—Three pairs of lophophoral cirri, fifth and sixth appearing in succession. Ventral side. Whole mount.
Fig. 30.—Five pairs of lophophoral cirri. Whole mount.
Fig. 31.—Six pairs of lophophoral cirri. Gastric caeca well formed. Whole mount.

All figures based on camera lucida drawings.



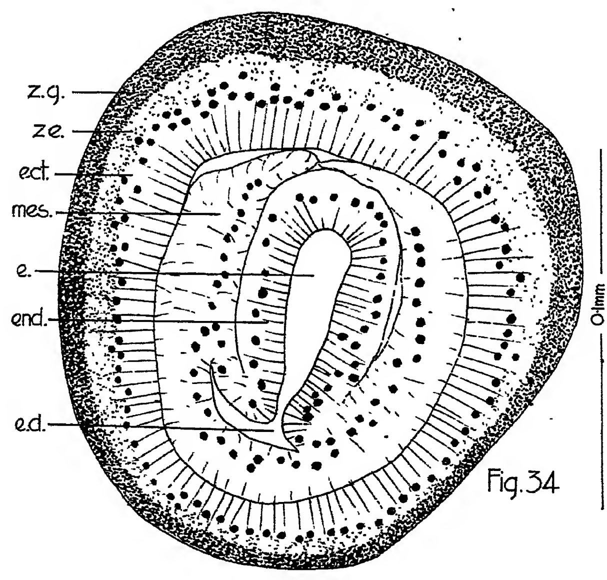


FIG. 32.—Nine pairs of large lophophoral cirri, and a nineteenth cirrus appearing. Inflection of anterior border of mouth producing a crescent-shaped slit. Whole mount.
FIG. 34.—Nearly horizontal section of slightly later stage than Fig. 33, showing mesoderm lying laterally to enteron, and posterior connexion between endodermal and mesodermal cavities.

All figures based on camera lucida drawings.

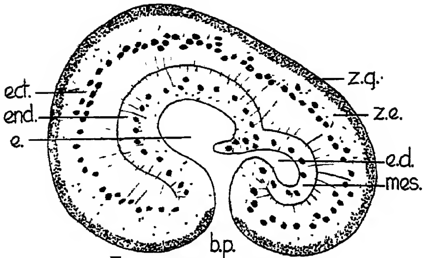


Fig 33

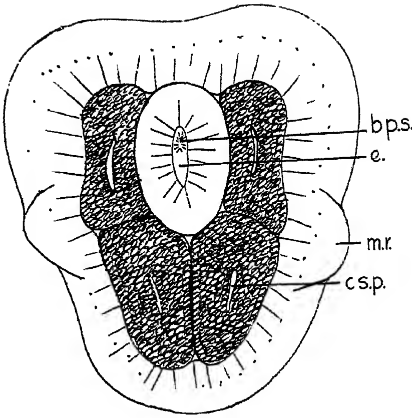


Fig.37

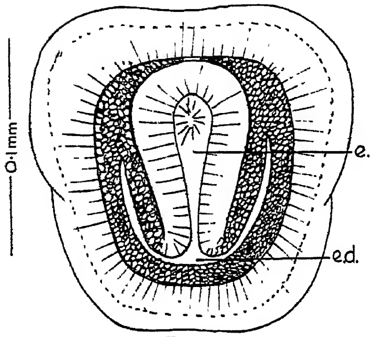


Fig.35

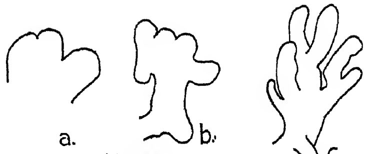


Fig.38

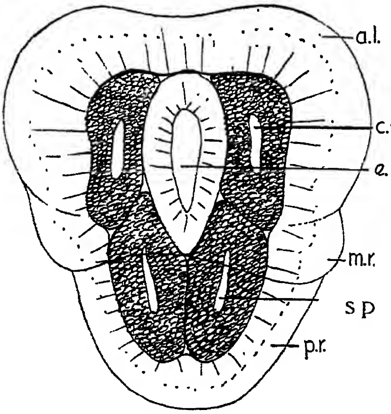


Fig.36

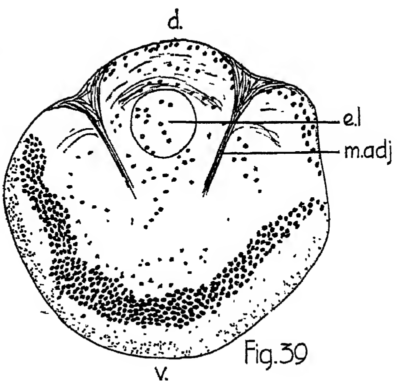


Fig.39

FIG. 33.—Sagittal section of late gastrula, wedge-shaped, showing posterior enterocoelic pouch opening from archenteron, and showing absence of granular layer from endodermal and mesodermal cells.
FIG. 35.—Optical section of same stage as Fig. 34, where anterior lobe is marked off and blastopore closed, showing posterior continuity between enteron and coelomic cavity. Whole mount.
FIG. 36.—Dorsal view at stage of appearance of mantle rudiment, showing right and left anterior and posterior coelomic sacs and restricted anterior position of enteric cavity. Whole mount.
FIG. 37.—Ventral view of same stage as Fig. 36. Whole mount.
FIG. 38 a, b, c.—Stages in elaboration of right gastric diverticulum.
FIG. 39.—Transverse section of base of mantle of late larva after emergence, showing dorsal (pedicle) adjustor muscles connected to dorsal surface.

All figures based on camera lucida drawings.

In the present study, it has been possible to follow one batch of material in development from early gastrula to fixation, but only one specimen survived to fix itself and it died before any further change took place. Two lots were killed and preserved daily and sketches were made similarly, so that a reliable set of records exists of that particular material. Another brood of larvae emerged naturally from a female and proceeded to fix, as has already been described. It was not possible in the circumstances to decide by direct external observation how the orientation of the newly-fixed larva was related to that of the young adult. There was no certainty that rotation did not take place, and the striking changes in the form of the anterior lobe precluded any following of the parts from one condition to another during a period of 24 hours or more. Thus, from that standpoint, there was little more hope of connecting larval and adult orientation than there was of linking Morse's and Conklin's observations.

The clue to the connexion lies, however, particularly in the presence in the late larva, while still free swimming, of a pair of muscles, right and left, passing from the peduncle forwards and upwards, each being attached dorso-laterally in the base of the mantle, the place of attachment being marked externally by a small indentation (Plate 7, Fig. 39). After mantle reversal, and for a short time later, these are the only muscles distinguishable. They are then connected with the larger mantle flap which produces the larger valve and are the so-called ventral adjustor muscles: they must now be renamed. In view of the fact that the adjectives "dorsal" and "ventral" have already been used on the understanding that the smaller and larger valves are dorsal and ventral, confusion would arise merely by changing their application. It seems therefore advisable to cease the usage of the words "dorsal" and "ventral" and to maintain the use of other terms such as are given by Thomson (11, p. 4). It seems that the words "pedicle" and "brachial" would well satisfy the need of the conchologist and palaeontologist as far as these are concerned with the Testicardines. *Lingula,* for reasons to be later considered, falls into another category.

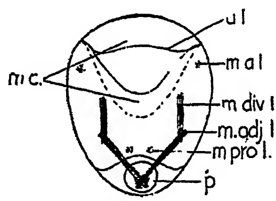
The "ventral sense plate" of Conklin is, in *Terebratella,* represented also by a well-marked thickening along the mid-ventral line of the mantle of the late larva, and, in section, is densely nucleated. In the present study, it is not seen to form anything significant in the newly reversed animal, and cannot yet be said to contribute anything important to the structure of the adult nervous system.

It becomes obvious that only by examination of material in various stages of transformation the relations of the parts of pre- and post-metamorphic can be decided. Quite truly, we must accept the view that the ventral side of the late larva is the same as that of the early one, or we must reject it. If the former, then the identification of the dorsum and the ventrum of the sedentary animal is easily possible by means of the musculature: if the latter, then at present there is nothing which has been found to persist throughout early life which might conveniently be used as a datum of reference. There is no reason to doubt that the greater dorsal curvature of the early larva remains until metamorphosis, and this determination,

based on a number of recorded steps, refers in the beginning to the position of the blastopore. Conklin's orientation, as far as it goes, agrees with the present one, except in the case of the gastrula when the enterocoelic sac is in formation.

The Appearance of Muscles.

It has been noted that the dorsal (pedicle) adjustor muscles appear before fixation, and that they enable the determination of dorsal and ventral surfaces after metamorphosis. When the apical lobe begins to show the earliest signs of remodelling, about the time when the valves show a slight size difference, four pairs of muscles are already present, the adductors, the protractors, the divaricators and the dorsal (pedicle) adjustors. At the first stage after mantle reversion, the mantle cavity is extensive, but undergoes reduction in depth, antero-posteriorly, when the body flattens, particularly along the sides. As a result, the mantle cavity becomes saddle-shaped with the ventral limb continually shortening as the anterior lobe is remodelled. Antero-laterally to the median portion of the cavity lie the right and left adductor muscles, well forward, relatively much more so than in the adult. The divaricators lie obliquely running backwards and upwards immediately behind the mantle cavity which also for a time projects backwards between them dorsally and ventrally. The pedicle adjustors converge obtusely towards the peduncle from sites closely associated with the dorsal ends of the divaricators. The protractors lie nearest the middle line between the adjustors and pass almost vertically between the valves.



TEXT FIGURE 3.
Diagrammatic ventral view of same stage as Text Fig. 2b, showing distribution of muscles and mantle-cavity.

When the muscles have appeared, the mesoderm is with difficulty recognisable as a distinct layer, the apical mass consisting, apart from the muscles and small endodermal body, of a uniformity of cells. Later, when the anterior lobe begins to reform, cell layers become distinct while forming stomodaeum and gut, but for some time there is little in the main mass to distinguish one germ layer from another.

As has been seen, addition to the length and width of the shell takes place chiefly at the edge of the valve, so that the mantle cavity increases in capacity. This makes possible the expansion of the anterior lobe during remodelling, and also brings about the location of the musculature in the posterior region. The elaboration of the mouth to form the lophophore proceeds concurrently with the growth of the shell.

The Vascular System.

The lophophoral cirri are solid until three pairs have appeared, when they and their successors become hollow with a single tube. The cavities later become continuous with a series of spaces round the gullet, and, as the lophophore becomes more intricate in its folding, so do the related spaces become more involved. The cirrial canals are early lined by an endothelium which continues throughout the perioesophageal sinuses. No sign of a heart-like organ has been found connected with this system of spaces, and no connexion has been found between these vascular spaces and the coelom.

The absence of any sign of a cardiac organ leads to the question of the causation of blood flow. The cirri are provided with longitudinal muscle fibres and a skeletal rod consisting of an inverted grooved strand which contains the vascular space. The groove is closed by the band of muscle fibres and the vascular endothelium lines the tube so formed.

If the skeleton be suitably elastic, it would tend to resume its original straight position after being bent by the muscle band. These bending and straightening movements are to be seen not commonly as in polyzoan tentacles, but they occur, and could serve in a crude way to help in blood circulation.

Gonocoele and Coelomoducts.

The adult has commonly four gonadial cords in the dorsal mantle, the two inner being unbranched, the two outer being branched on the outer sides. Two cords lie in the ventral mantle, with outer branches. The dorsal cords are in two pairs, right and left, each pair having a common base on the wall of the common coelom. The ventral cords lie separately, posteriorly, each on its own side of the common coelomic wall. No visible connexion occurs between the dorsal and ventral cords. The gonadial masses arise as proliferations from the walls of the gonocoeles, and ultimately fill these spaces at sexual maturity.

At a size of 1·5 mm. long and 1 mm. broad, about eleven months of age, the gonocoeles appear as diverticula of the common coelom. The ventral sacs at first project into the wall immediately behind the angle formed by the stomach and the blind gut. They pass forward a short distance and then emerge as thin walled sacs projecting into the common coelom one on each side of the gut. At this stage they are quite short and project no further toward the ventral mantle. The dorsal gonocoeles are a pair of dorsal projections of the common coelom into the tissue of the dorsal mantle and may show indications of primordial germ cells. No subdivision has yet taken place.

The coelomoducts are two, right and left, and, at the end of the first year, lie horizontally as blind diverticula of the coelom terminating forward at each end of a transverse fold a little behind the mouth. The internal ends of the coelomoducts are yet plain funnels and the walls distinct and one cell thick. Later, at earliest sexual maturity about the end of the second year (length 6 mm., breadth 4 mm.) the ducts have acquired external openings. Their position has changed in accordance with a general rearrangement

of parts through growth in the previous year. They lie on the anterior wall of the common coelom, their course being somewhat vertically upwards. The internal openings are now plicated funnels and the wall is clearly ciliated. An immature specimen of this size showed no sign of external opening.

The coelomoducts may be primarily gonoducts, since they have been found closed until sexual maturity. Up to the stage of ten pairs of cirri, no sign of either gonocoele or gonoduct has been found. Excretion may, therefore, take place through the general ectoderm, but later also through the open gonoduct.

Comparative Embryology.

Thomson (*op. cit.*, pp. 32-4) summarises the, then, knowledge of brachiopod development. It will serve today as a satisfactory source of modern information.

It appears that the close studies of embryology are those of Yatsu (12) on *Lingula* and Conklin (*op. cit.*) on *Terebratulina.* Kowalewski (3) contributed valuable information and figures about the development of *Argiope* and *Thecidium.* These developments fall into two well marked groups, one containing *Lingula* and the other containing the rest. These two groups naturally coincide with Ecardines and Testicardines.

Those in the second group, *Terebratella, Terebratulina, Argiope, Thecidium,* are uniform in that the larva consists of apical lobe, sheath-like rudiment of mantle and peduncle, and that metamorphosis proceeds by reversion of the mantle. Gastrulation is commonly by invagination and, where the origin of the mesoblast is known, there is usually found an enterocoelic diverticulum. Segmentation of the fertilised egg, where known, is generally similar, with the gradual growth of a spherical blastula.

Dawydoff (2, p. 330, Fig. 146) figures, after Kowalewski, a pair of lateral enterocoelic pouches from which the mesoderm of *Argiope* is said to arise. Oehlert and Deniker's analysis of Kowalewski's work (*op. cit.*) shows the mesoblastic sacs of *Argiope* as coming from the end of the enteron in somewhat the same way as they do in *Terebratella* and *Terebratulina.* Sedgwick (10, p. 582) says that "the last remnant between the two" (i.e., mesoblast sacs and enteron) "is at the front end of the body." This statement is quite reasonably based on the Fig. 3 of Oehlert and Deniker's analysis. In Figs. 4 and 6 of this analysis, there is seen a set of relations between coelomic sacs and enteron very similar to that in *Terebratella.* The question arises, therefore, is the primary enterocoelic pouch of *Terebratulina* and of *Argiope* anterior or posterior in origin? Kowalewski had not available to him the technique of modern microtomy and Conklin was unable to study his material alive. In these cases, it would be possible to mis-orientate small objects through inability, due to force of circumstances, to relate a given external form of live larva with a given internal arrangement. We need, therefore, further information about these matters.

Morse concluded that the lophophore of *Terebratulina* arose outside of the mouth, Kowalewski thought that the cirri of *Argiope* were formed from mantle and concluded that in *Thecidium* the anterior

lobe made a contribution. The gut of *Terebratella* passes backwards and upwards, without an anus.

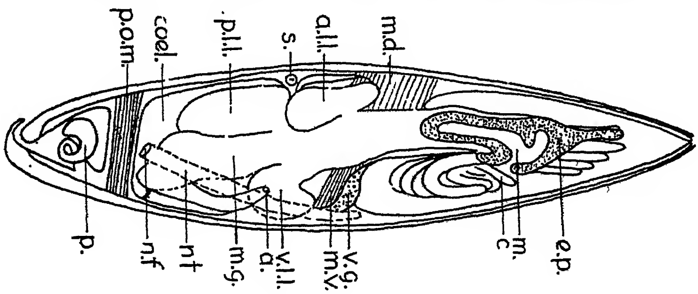
Lingula stands in sharp distinction from those above-mentioned in its early development. It has a relatively long embryonic life, emerging from the egg membrane about the time of appearance of the first pair of cirri. Segmentation gives rise to a blastula consisting of two apposed layers each of 16 cells, similar to the condition in phylactolaematous Polyzoa, as shown by Yatsu. The mesoderm arises as two lateral proliferations from the endoderm, and the coelomic spaces are schizocoeles. The mouth arises on the site of the closed blastopore and is ventral in position, the lophophore is definitely extra-oral in origin, the gut continues backwards, downwards, and forwards to open by an anus. The mantle begins as a posterior circular flange which later becomes bilobed, the peduncle appears late, having a quite different kind of origin and constitution from that in *Terebratella* and *Terebratulina*, and, by development, the small valve is dorsal and the large one ventral. The peduncle is related to the large valve. Thus, the orientation of *Lingula* is essentially that of the embryo, without any remodellings or reversals to make possible drastic rearrangements, the adult being achieved without metamorphosis.

It becomes clear that between *Lingula* and *Terebratella* (along with the other Testicardines) there are profound differences in development. Many of the striking facts have already been reviewed immediately above. Included in them must be the nature of the shell of the adult. Thomson (*op. cit.*, p. 115) mentions that the shell of his Gastrocaulia (approximately equal to the Ecardines) is of chitinophosphatic material (tricalcium phosphate and chitin or keratin, see Thomson, p. 96), or of something derived therefrom. The shell of his Pygocaulia (approximately equal to the Testicardines) is calcareous (i.e., of calcium carbonate) and for the most part with fibrous prismatic structure (*op. cit.*, p. 116). These shell differences indicate very sharp physiological differences, which are properly taken into account in the systematic arrangement of Brachiopoda.

It seems, therefore, that Brachiopoda consist of two very sharply differentiated groups, from the standpoints of embryology and physiology. Indeed, the adult features of Ecardines (Gastrocaulia) and Testicardines (Pygocaulia), which are regarded as common, may be quite properly looked at as convergent and as in no way indicating a common origin. Sedgwick (10, p. 572) defines the phylum Brachiopoda as "Fixed, solitary, apparently unsegmented Coelomata, with a tentaculated buccal groove often prolonged into arms, and a bivalve shell." This statement says the least about the phylum, yet enables the distinction of a brachiopod from any other animal, serving until it is possible to inquire more specifically into the constitution of the phylum.

The accepted orientation of the brachiopod body seems to have been based on the assumption of the homology of the structures in the group as a whole. The dissimilar valves, the lophophore, the position of the mouth, the bent gut, the nervous system, the peduncle could all be conceived as homologous without any knowledge of early development, but as soon as this is known it becomes clear that the assumption of homology is to a considerable extent, if not entirely,

false. The brief review, in this section, of the chief developmental and physiological features of *Lingula* and the Testicardines, taken with a knowledge of the function of the adult structures, particularly the lophophore, justifies the conclusion that *Lingula* and, for instance, *Terebratella* show a high degree of convergence, and, from the standpoint of Brachiopoda, show nothing that is acceptable as divergence—i.e., from a common ancestor. It appears not unreasonable, in the light of the foregoing, to consider the separation of *Lingula* and its allies completely from *Terebratella* and its allies, even to the extent of placing them in separate phyla, as has been done with Polyzoa Ectoprocta, and Polyzoa Endoprocta. Lowenstein (4) has placed these under the phyletic names of Bryozoa and Calyssozoa respectively, thus resolving a difficulty which has been long apparent.



TEXT FIG. 4.—*Lingula anatina* with 10 pairs of cirri (after Yatsu).
a., anus; *a.l.l.*, antero-dorsal lobe of liver; *c.*, cirrus; *coel*, coelom; *ep.*, epistome; *m.*, mouth; *m.d.*, dorsal mesentery; *m.g.*, mid-gut; *mv.*, ventral mesentery; *n.f.*, nephridial funnel; *n.t.*, nephridial tube; *p.*, peduncle; *p.l.l.*, postero-dorsal lobe of liver; *p.o.m.*, posterior occlusor muscle; *s.*, statocyst; *v.g.*, ventral ganglion; *v.l.l.*, ventral lobe of liver.

To whatever lengths the students of Brachiopoda may go in arranging their material, it seems clear that Pygocaulia and Gastrocaulia are inadequate as sub-classes. Too much similarity is implied, when the fact is that so much difference exists. Further knowledge about the development of the relatives of *Lingula* will throw light on this very important problem in Brachiopod systematics.

SUMMARY.

1. The development of *Terebratula inconspicua* has been studied from material gathered in Lyttelton Harbour, New Zealand.
2. The breeding season is in April and May.
3. Segmentation is equal, producing a blastula which gastrulates by invagination. The gastrula is ciliated.
4. The blastopore closes completely and all trace vanishes.
5. An apical tuft of long cilia is present for part of the development which proceeds considerably in the female mantle cavity.
6. The mesoderm originates as a posterior enterocoelic pouch which ultimately separates into right and left sacs. The sacs divide into anterior and posterior segments.
7. The embryo differentiates first into a ciliated anterior lobe with apical tuft and an unciliated posterior peduncular rudiment.
8. The mantle rudiment arises as a transverse dorsal fold bordering posteriorly the apical lobe, and passes downward laterally, the two sides ultimately joining to complete the fold ventrally.
9. The mantle rudiment extends backwards to ensheath the narrowing peduncle. It ultimately bears four tufts of marginal setae.
10. The larva on leaving the mantle cavity bears a ring of pigment spots on the posterior border of the apical lobe.

11. On attachment by the peduncle, the mantle sheath reverses and encloses the apical lobe which flattens dorso-ventrally, leaving a slit-like opening to the mantle cavity now formed.
12. The apical lobe is reshaped and is extended on the inside of the ventral valve, the valves by now having been calcified.
13. The stomodaeal invagination is a dorsal invagination on the reshaping anterior lobe and grows in to join the appearing gastric cavity which arises in a solid endodermal mass, the original enteron having disappeared.
14. A pair of dorsal adjustor muscles appears before metamorphosis, in the late larva, formed from the posterior coelomic sacs, and shows the pedicle valve, formerly called ventral, to be dorsal. The other muscles appear early after reversal.
15. The mesoderm early becomes solid and the adult coelomic cavities appear later about the time when the adult gastric diverticula appear. The germinal cavities are extensions of the adult coeloms.
16. The lophophoral cirri are formed from the edge of the mouth.
17. An attempt has been made to determine the life history of a population.
18. *Terebratella* and *Lingula*, in development, are compared and contrasted. It is proposed that the differences are so great that the adults are convergent in structure.

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ABBREVIATIONS.

a.l.	anterior lobe.	m.	mantle before reversal.
a.s.	adult seta.	m^1.	mantle after reversal.
a.t.	apical tuft.	m.a.l.	left adductor muscle.
bp.	blastopore.	m.adj.l.	left dorsal adjustor muscle.
bp g.	blastoporal groove.	m.adj.l^1.	left ventral adjustor muscle.
bp.s.	blastoporal site.	m.c.	mantle cavity.
c.s.a.	anterior coelomic sac.	m.div.l.	left divaricator muscle.
c.s.p.	posterior coelomic sac.	mes.	mesoderm.
d.	dorsal side.	m.pro.l.	left protractor muscle.
e.	enteron.	m.r.	mantle rudiment.
ect.	ectoderm.	mth.	mouth.
e.d.	enterocoelic diverticulum.	oes.	oesophagus.
e.l.	solid larval endoderm.	p.	peduncle.
e.m.	edge of mouth.	p.r.	peduncular rudiment.
end.	endoderm	s.	seta.
e.r.	rudiment of adult enteron.	s.r.	stomodaeal rudiment.
e.s.	pigment spot.	st.	stomodaeum.
f.	follicle cell.	v.	ventral side.
g.d.	gastric diverticulum.	v.d.	dorsal or pedicle valve.
i.b.m.	inflected border of mouth.	v.v.	ventral or brachial valve.
int.	intestine.	z.e.	eosinophil zone.
l.c.	lophophoral cirrus.	z.g.	zone of granules.

* The writer is indebted to the Council of Canterbury University College for a

Vol. 74, Part I, pp. 24–31, Plates 8–9.

Pellibranchus cinnabareus, a New Genus and Species of Non-Pelagic Nudibranch Mollusc of the Family Phyllirhoidae.

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Pellibranchus cinnabareus n.g., n.sp. is a small Nudibranch which up to the present time has been found only at Island Bay, Wellington, New Zealand. The limaciform adult, bright red in colour, lacks external gills and other appendages with the exception of a pair of relatively long tentacles on the head. The adults are found at all seasons of the year on the lower surface of stones in tidal runnels along the shore. The general form resembles that of a small lithophilus Elysiomorph but the uniform bright red colour extending over the sides and the foot, the possession of a multiseriate radula, and the division of the hermaphrodite gland into male and female acini enable the separation of this species from the known New Zealand Nudibranchs similar in size and habit. Packets of three to twenty-four eggs the same colour as the adults, are found from September to May. Development is direct, the animal hatching in the juvenile form. Graphic reconstruction after the technique of Wells (*Proc. Zool. Soc.*, 1922, Part 4) was employed in determining much of the internal morphology.

The writer wishes to express her thanks to Professor H. B. Kirk for his valuable guidance and advice. The work has been conducted in the laboratory of the Biology Department, Victoria University College.

Systematic Position.

Pellibranchus cinnabareus belongs to the Sub-order Dendronotaceae (Odhner, 1936) including " holohepatic or cladohepatic Nudibranchs with the right liver smaller than, but similar in structure to the left. No blood gland. Only one vesicula seminalis. Rhinophores retractile into sheaths. Anus lateral or latero-dorsal in the interhepatic space." It is referred to the family Phyllirhoidae (Odhner, 1936) since it possesses the " Back margin entirely reduced as well as the cerata. Anus lateral or dorsal. Liver consisting of two dorsal coeca (right and posterior liver) and one ventral (left anterior liver) all simple tubuliform. Rhinophore club smooth (in contraction falsely laminated); sheaths very small. Jaws covering the frontal side of the pharynx. Gonad in a few globular masses or floccular stripes. No prostata and no bursa copulatrix (but a muscular vesicula seminalis in the end of the oviduct). Nephroproct in the middle of the right side. Eyes with indistinct optic nerves."

It should be noted here that *Pellibranchus* is benthic and not pelagic as are the other members of the family Phyllirhoidae and shows a remarkable convergence with the genus *Cenia* (Alder and Hancock) Sub-order Sacoglossa (Ascoglossa) in habitat and external form.

Pellibranchus differs from *Cenia* in having the hermaphrodite gland divided into male and female acini instead of spheroidal hermaphrodite lobules, genital orifices contiguous not distant, the anus in the second quarter of the body not posterior, and a multiseriate not uniserial radula. These features of *Pellibranchus* clearly place the genus within the Sub-order Dendronotaceae and establish the similarity in external form of *Pellibranchus* and *Cenia* as one of simple convergence.

Odhner (1936) defines two genera in the family *Phyllirhoidae*:

"Genus: 1. PHYLLIROE Péron and Lesueur.

Body elliptical without a foot. Anus lateral, dextral. Gonad in spheroidal globuli. Liver coeca four (two superior and two inferior ones). Head without a disc. Jaws with *processus masticatorius*. Radula well developed, with a few lateral teeth denticulate in the inner edge and a median tooth denticulate on both sides. Penis cylindrical, tube-like; its glans armed with conical papillae and with a large sub-apical lobe.

Genus: 2. CEPHALOPYGE Hanel.

Body elongate, lanceolate, with a distinct foot. Anus dorsal close behind rhinophores. Gonads flocculent, in stripes or in clusters of folliculi. Liver coeca usually 3 (a single dorsal one, a single ventral as a rule, and a posterior). Head with a disc. Jaws without the *processus masticatorius*. Radula often obliterated. Penis conical and unarmed."

The present species possesses a distinct proboscis; rhinophores linear, bluntly tipped and retractile, about a millimeter in length; hepatic caeca three, all bluntly lobed; rectum directed forwards; anus opening in the mid-dorsal line in the second quarter of the body; foot quite distinct and terminating in a tail; penis armed with hooked spines; accessory genital glands present; hermaphrodite gland divided into male and female acini, with distinct male and female ducts; penial and vaginal apertures surrounded by a conical copulatory pouch which can be extruded through the genital aperture on the right side of the body; jaws wanting but the buccal bulb armed internally and externally with a supporting connective tissue sheath, which forms a cone of sclerites round the true mouth; radula narrow, formula 1.2.0.2.1.; development direct.

These features are distinct from those of the existing genera in the family, and it is therefore proposed to erect a new genus with the following characters:—

Genus: 3. PELLIBRANCHUS nov.

Body limaciform with a distinct foot. Anus opening about the mid-dorsal line in the second quarter of the body. Gonads divided into male and female acini, the female lobes spherical, the male lobes more elongate. Liver caeca three (a left anterior dorsal liver, large posterior liver and right anterior liver poorly developed). Head without a disc. Jaws without *processus masticatorius*. Radula well developed. Penis armed with hooked spines.

Genotype: **Pellibranchus cinnabareus** n.sp. Wellington, N.Z.

P. cinnabareus is unique in the family Phyllirhoidae in the relation of the anus and nephroproct, the absence of functional jaws, the thick body wall with uniform ciliation, and in its non-pelagic habit. Within the family it resembles *Phylliroe* in having the nephroproct in association with the anus but is unlike that genus since these structures in *P. cinnabareus* are in the dorsal position whereas in *Phylliroe* the nephroproct is on the right side of the body. The association of the nephroproct and anus is general in the Dendronotaceae (Odhner, 1936), but in the members of the family Phyllirhoidae the nephroproct lies about the middle of the right side and lacks constant relationship with the anus. Accordingly too much significance may not be attached to this feature in the family.

Pellibranchus has no chitinous sclerites in the buccal bulb that could function as jaws in the usual meaning of the word, but covering the bulb internally and externally is a membranous connective tissue sheath, forming round the frontal portion of the true mouth a cone of sclerites usually twelve in number. The writer has not observed that these function as jaws. There is some variation in the shape of the jaws in other members of the family, *Cephalopyge* being without the usual *processus masticatorius* of *Phylliroe.* Odhner (1936) considers this the primitive condition.

Pellibranchus is more nearly allied to *Cephalopyge* than to *Phylliroe* both genera having a distinct foot and dorsal anus. In *Cephalopyge* there are usually three liver caeca, but the number and size is variable. In *Pellibranchus* the liver is more compact, with three well defined caeca in which the left anterior liver appears dorsal in position, not the right as is the case with the other members of the family. The right hepatic caecum in *Pellibranchus* is ventrolateral in position and generally obscured in lateral view by the anterior genital mass. (Plate 9.) Odhner (1936) discussing the difference in the liver structure of the closely allied genera *Fimbria* and *Melibe* considers that the differences "may be due to the various formation of the gonad which stands in intimate correlation to the liver." Possibly the great development of the anterior genital mass in *Pellibranchus* can be correlated with the reduction of the right anterior liver. Slight divergence is seen in the fact that *Pellibranchus* has bluntly lobed caeca, while in *Cephalopyge* these structures are simple and tubular, although too much significance may not be attached to this distinction as Hoffman (1906) states that Vesschelli observed some variation in the liver of *Phylliroe,* where one specimen bore a few small diverticulae and in another they were totally atrophied.

Odhner (1936) further states that "the liver of nudibranchs shows a tendency to disintegrate from a compact to a more or less branched organ, and that the liver may consequently show the same stages of disintegration in different families, as well as different stages within the same family; therefore it is not apt as a direct indicator of relationship."

The absence of a disc on the head of *Pellibranchus* further distinguishes it from *Cephalopyge,* and the distinct nature of the two

genera is established by the following structures of *Pellibranchus*: the penis is armed with hooked spines; no ampulla is developed on the hermaphrodite duct; an albumen gland is present as well as a mucous gland; separate male and female ducts leave the hermaphrodite gland. At the same time the known species of *Pellibranchus* superficially resembles *C. trematoides,* being very similar in size, shape and colour, but the number of gonads in *P. cinnabareus* is seven, two ventral sperm lobules, and five dorsal ovarian lobules, whereas in *C. trematoides* there are five hermaphrodite lobules.

Although the genus *Pellibranchus* is assigned to the family Phyllirhoidae it may be necessary ultimately to create a new family or amend the present family definition to include this genus on account of its unique features, but the writer at present is unwilling to do this in view of the general agreement with the existing genera.

EXTERNALS.

Pellibranchus cinnabareus is a small, bright red marine slug, exhibiting external symmetry. The body is arched, limaciform, with the dorsal and lateral surfaces smooth. The colour is uniform over the body except the tips of the rhinophores and the tail, which are a paler vermilion. The body appears granular, and when the animal moves wave-like ridges pass over the entire surface of the animal. The visceral hump grades imperceptibly into the foot, which is simple and terminates in a small pointed tail into which the viscera do not extend. The liver shows through the lateral body wall as a dark green brown mass. The eyes appear as small black dots situated behind the tentacles and in a straight line with the tentacular base. The size of sexually mature animals ranges from 3 mm. to 6 mm. with an average length of 4 mm. and vertical central diameter of 1·5 mm.

INTERNAL ANATOMY.

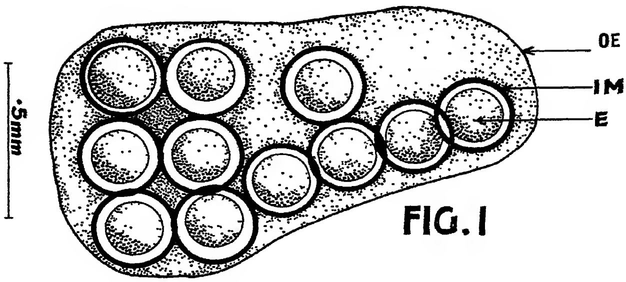
The structure of the body wall and associated connective tissue has been described by several workers for the genera *Cephalopyge* and *Boopis*. In many respects *Pellibranchus* shows a body-wall structure different from that of these two genera, but glands similar in structure to those described for these two genera are found in *Pellibranchus* opening between the epidermal cells and are most numerous in the foot and tail region. In the present species the epithelium is ciliated and columnar over all parts of the body, and the body wall is heavy. This is not the case with the other two genera of the family where the epidermis is flattened and unciliated and the body wall on the whole much thinner. The prominent longitudinal muscle strands described by Stubbings (1937) for *Cephalopyge* and Dakin and Colfax (1936) for *Ctilopis picteti* (*Cephalopyge orientalis*) are not distinguishable in *Pellibranchus*. In the central dorsal aspect of the body of *Pellibranchus,* is a large branched multicellular slime gland opening to the exterior close to the anus. Hecht (1895) described an anal gland in the Nudibranch *Proctonotus mucroniferus*. In *Proctonotus* the gland opens into the intestine, but in *Pellibranchus* it opens directly to the exterior.

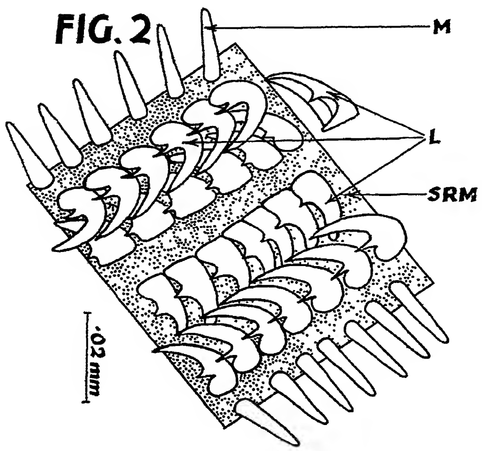
The alimentary canal (Plate 9) comprises in general a buccal bulb with the related structures of radula and odontophore, a long oesophagus, stomach, intestine and digestive gland or " liver ".

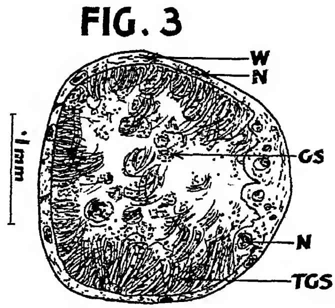
The buccal bulb is pear-shaped, enclosing the radula and odontophore with their accompanying muscular attachments. The odontophore "cartilages" usually present in molluscs (Pelseneer, 1906) appear to be absent in *Pellibranchus*. In almost the same position as the cartilages in other molluscs, and immediately under the sub-radula membrane is an infraradula sheet of longitudinal muscle fibres. These are inserted dorso-laterally on to the large circular muscle fibres of the odontophore. Inserted on to the ventro-lateral portion of the odontophore are longitudinal muscle fibres that have their origin in and are continuous with the ventro-lateral external longitudinal muscle fibres of the buccal bulb. The radula sheath lies embedded in the muscle fibres at the posterior end of the buccal bulb. The radula has quite a sharp ventral bend bringing it to the under side of the odontophore, where it passes round the end of its flexible muscular support. The radula and odontophore are capable of extrusion through the opening of the true mouth—i.e., the aperture of the buccal bulb, by the contraction of protractor muscle fibres—those inserted laterally on to the odontophore. The entire buccal bulb can be drawn forward through the puckered orifice on the ventral surface or back into the introvert by contraction of retractor muscle fibres passing from its walls to the body wall.

Pelseneer (1906) has distinguished several varieties of protrusible molluscan buccal bulbs. The proboscis of *Pellibranchus* is pleurecbolic since when evaginated the oesophagus forms its inner lining and when invaginated its posterior continuation. A relatively thick membranous connective tissue sheath covers the bulb internally and externally forming twelve plate-like projections round the true mouth. These do not function as jaws. There are relatively large vascular lacunae scattered between the muscle layers of the buccal bulb.

The radula (Plate 8, Fig. 2) is narrow and formed of distinct but colourless teeth. In the absence of a central tooth the thin sub-radula membrane is visible down the centre of the ribbon. There are three rows of teeth on either side of the sub-radula membrane, two rows of laterals and one row of marginals. The teeth of the first row of laterals are grooved and the side of each tooth distant from the sub-radula membrane tapers away under the second row of laterals. Each tooth has a small, forwardly directed spinous process which emerges from the middle of the anterior margin of the tooth. The next row of laterals consists of crescent-shaped teeth broadly rounded laterally and with a sharp, spinous process arising from the concave anterior surface just medial to the rounded portion. The radula formula is thus 1.2.0.2.1. In each of the six rows of teeth of a sexually mature animal there are 45 individual teeth, making a total of 270 teeth in all. The oesophagus enters the buccal cavity dorsally by a narrow duct. As the oesophagus emerges from the buccal bulb it narrows and flexes down toward the ventral surface. About the mid-point of the body the oesophagus again flexes dorsalwards and opens into the stomach. The stomach is a broad chamber. Ducts from the left and posterior liver enter the stomach dorsally and from the right liver laterally. The intestine is a narrow, thick walled ciliated duct







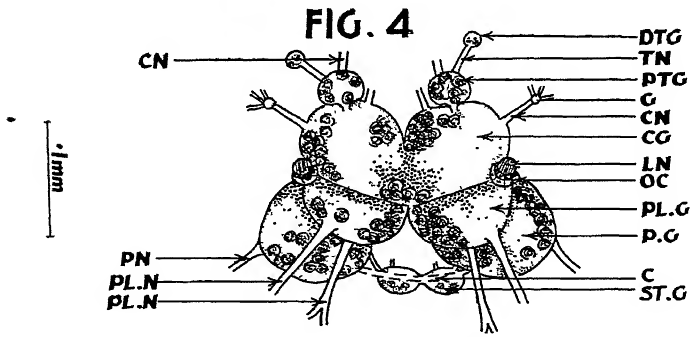


Fig. 1. Packet of Eggs.

Fig. 2. Portion of Radula. Fig. 3. T.S. Kidney.

Fig. 4. Reconstruction of the Central Nervous System. (Dorsal view.)

EXPLANATION OF LETTERING.

AG., albumen gland; AHC., anterior hepatic caecum; AU., auricle; BB., buccal bulb; C., pedal commissure; CG., cerebral ganglion; CF., copulatory funnel; CN., cerebral nerve; DTG., distal tentacular ganglion; DVS., duct from vesicula seminalis to oviduct; E., egg; F., foot; G., ganglion; GS., granules embedded in ground substance of kidney; IM., inner membrane of egg; INT., intestine; K., kidney; KD., kidney duct; L., lateral teeth of radula; LN., lens; M., marginal teeth of radula; MG., mucous gland; N., nucleus; OC., optic cup; OD., oviduct; OE., outer envelope surrounding all the eggs; OES., oesophagus; OL., ovarian lobule; PG., pedal ganglion; PHC., posterior hepatic caecum; PL.G., pleural ganglion; PL.N., pleural nerve; PN., pedal nerve; PTG., proximal tentacular ganglion; S., sclerites; SL., sperm lobule; SRM., sub-radula membrane; ST.G., stomatogastric ganglion; T., tentacle; TA., tail; TGS., thread-like ground substance of the kidney; TN., tentacular nerve; V., ventricle; VD., vas deferens; VE., vas efferens; VS., vesicula seminalis; W., wall of kidney.

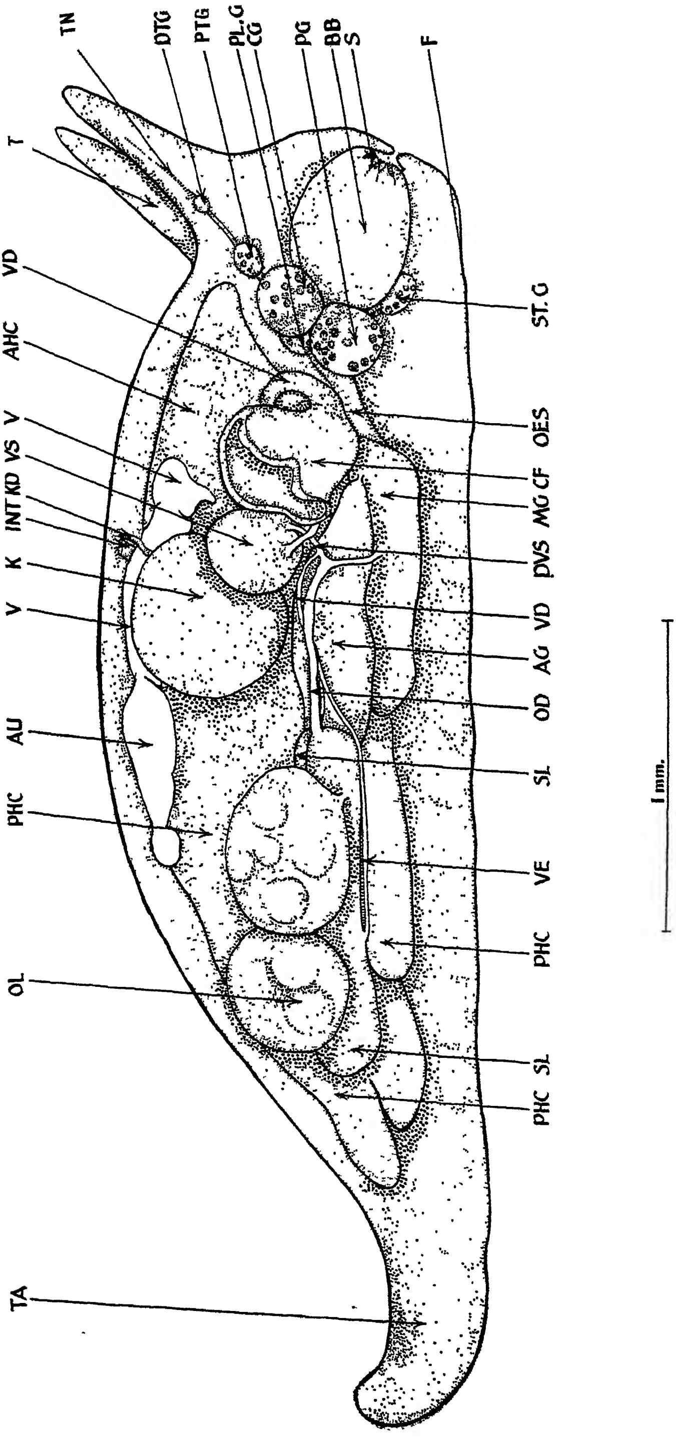


Fig. 1.

Diagrammatic view of *Pellibranchus cinnabareus* reconstructed from whole mounts and serial sections. (Lateral view.)

running from the upper left surface of the stomach. It travels on the left side of the body as far forward as the kidney, then flexes to the right, passes above the oesophagus and opens to the exterior slightly lateral to the mid-dorsal line. Salivary glands were not identified.

The nervous system (Plate 8, Fig. 4 and Plate 9) consists of a circumoesophageal nerve ring of six large ganglia, cerebrals, pleurals, and pedals. The cerebrals, like those described by Dakin and Colfax (1936) for *Ctilopis picteti* (*Cephalopyge orientalis*) are in apposition. The pleurals about half the size of, and lying behind the cerebrals are not continuous but marked off from the latter by distinct furrows. The pedal ganglia are of approximately the same size as the cerebrals but set more to the lateral aspect of the oesophagus, bringing them into contact with the cerebrals and pleurals, but distant from each other, and it is difficult to trace the sub-oesophageal commissure connecting them. This condition is similar to that described by Dakin and Colfax (1936). The stomatogastric ganglia lying close together under the oesophagus are joined by commissures to each other and the cerebrals. Three nerves from the anterior, dorsal and lateral aspects of the cerebrals can be distinguished in *P. cinnabareus*. The dorsal nerve is ganglionated, and this corresponds closely to the conditions existing in *Ctilopis picteti* (*Cephalopyge orientalis*) where two of the nerves emerging from the cerebrals are ganglionated.

The eyes lying under the epidermis in close contact with the cerebral ganglia are similar in structure to the gastropod eye described by Pelseneer (1906) and innervated from the cerebrals by a very short nerve entering the base of the optic cup. In *P. cinnabareus* the otocysts touch both the cerebral ganglia and pedal ganglia, as is the general rule, but I have been unable to trace a nerve connection with either of these ganglia. The rhinophores differ in form from the other members of the family but in internal structure are similar, showing very well the numerous deeply staining round or ovoidal cells which Stubbings (1937) in *Cephalopyge arabica* considers as similar to the gland cells described by Pierantoni for other members of the family. The nervous system is similar in most respects to the other members of the family but differs from them in having the cerebral and pleural ganglia as distinct entities, instead of being fused to form cerebro-pleurals. Also the eyes of the present species are not " simple pigment spots " as in *Cephalopyge arabica* but have a definite optic cup and lens.

The excretory system (Plate 8, Fig. 3 and Plate 9) consists of a simple spherical kidney situated dorso-laterally in the middle of the body. A narrow ciliated duct runs from the dorsal surface of the kidney opening externally just in front of the anus. No trace of a renopericardial duct could be found. The spherical form of the kidney appears to be unusual. Pelseneer (1906) states that in the majority of molluscs the kidney is a compact lobed mass, and in a large number of Nudibranchs (*Doridomorpha*, *Janus*, etc.) the kidney is highly ramified. Histologically the kidney of *P. cinnabareus* has very much the appearance of a disintegrating gland. The outer wall of the kidney is thin with prominent nuclei. The main portion shows

granules embedded in a thread-like ground substance in which no cellular structure is visible. Hecht (1895) figures a cross section of the kidney of *Doris tuberculata* in which the walls are thrown into folds and the cavity filled with long cilia. If the cellular walls broke down in the kidney of *Doris tuberculata* a structure very similar in appearance to the kidney of *P. cinnabareus* would result. The disintegrating appearance of the kidney is probably of some importance in distinguishing the present genus when it is pointed out that in the anatomical sub-division of the family Phyllirhoidae given by Dakin and Colfax (1936) the classification is based on the presence or absence of a renal organ. This is the only attempt I have seen of a primary sub-division of the family on this basis. Cells in other regions of the body, namely certain cells of the "liver" and the numerous "Cells of Leydig" in the body wall probably perform the function of excretion as has been indicated by Hecht (1895) for *Doris tuberculata* and *Eolis glauca* and Yonge (1926) for several other Nudibranchs.

In the vascular system (Plate 9, Fig. 1) the heart is dorsal just beneath the connective tissue of the body wall and to the anterior end of the body. The ventricle is anterior to the auricle and separated from it by a muscular constriction. Ventricle and auricle are of almost equal size, and the pericardium is very poorly developed, consisting of only a thin layer of loose connective tissue. There are no respiratory organs in *P. cinnabareus*.

The reproductive system (Plate 9) is divided into two portions, the hermaphrodite gland and the anterior genital mass, the ovarian and sperm ducts being present as a bridge between the two. The hermaphrodite gland is elongate, composed of several contiguous acini bound together but separated by a limiting membrane. The lower portion is divided into two sperm lobules and the upper into five ovarian lobules, of which there are two on the right side and three on the left. This arrangement has been in general constant for the adult specimens examined. The ovarian lobules open into the lower sperm lobules. Opening from and running beneath each sperm lobule are delicate narrow vasa efferentia which unite at the anterior end of the foremost sperm lobule and enter the duct from the vesicula seminalis just before its junction with the upper ovarian duct. The vesicula seminalis is spherical, with thin muscular walls. The vas deferens leaving the vesicula coils back on itself in an "S" shaped bend and opens into the penis. The penis is oval and armed with hooked spines. The oviducal portion of the female organs consists of an albumen-mucous gland complex. The albumen gland lies mainly above and opens into the dorsal surface of the mucous gland. The mucous gland is sac-like and continuous with the vagina. The end of the vas deferens, penis and vagina are enclosed in a conical pouch covered with long cilia on the free edge and outer surface. There appears to be two kinds of motile sperm, some that are relatively large in size with pointed head and long tail twisted just below the head and others that are much smaller in size. Up to the present I have been unable to discover which kind of sperm fertilises the eggs. So far it has not been possible to distinguish the two kinds in the spermary.

The writer has not observed the oviposition of eggs (Plate 8, Fig. 1), but has found them at the eight celled stage and apparent blastula stage 21 days and 23 days respectively after copulation. The eggs are found in the same habitat as the adults. The number deposited varies from three to 24, with an average of 12 based on 50 packets. Investing the egg is a clear, thick membrane. Each egg membrane adhers to its neighbour where it touches, and enclosing all the eggs is a thinner clear capsule which is fastened to the surface of the rock. The eggs are spherical and have the same uniform vermilion colour as the adults. Eggs have been found in the natural habitat from September to May. Segmentation follows the usual spiral pattern, and development is direct, the animal hatching in the juvenile form. Pelseneer (1899 *Trav. Stat. Zool. Wimereux*, vol. vii) has described direct development in the Nudibranch *Cenia cocksii*, but this work is not available to the present writer and no comparison can be made.

SUMMARY.

Pellibranchus cinnabareus n.g. n.sp. is described and assigned to the Sub-order Dendronotaceae, Family Phyllirhoidae. The new genus is characterised by: a limaciform body with distinct foot. Anus opening about the mid-dorsal line in the second quarter of the body. Gonads divided into male and female acini, the female lobules spherical, the male more elongate. Liver caeca three (a left anterior dorsal liver, large posterior liver and right anterior liver poorly developed). Head without a disc. Jaws without *processus masticatorius*. Radula well developed. Penis armed with hooked spines.

Within the family *Pellibranchus* appears most closely allied to the genus *Cephalopyge*. Up to the present time specimens are known only from Island Bay, Wellington, New Zealand.

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The Titi Wainui or Fairy Prion *Pachyptila turtur* (Kuhl).

Part I.

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This paper is the fourth of a series dealing with sea birds on the small island of Whero, close to Halfmoon Bay, Stewart Island, New Zealand. The first two have been published in *The Emu* (1942, pp. 85–105 and 1943, pp. 24–48, 97–107) and the third in the *Transactions, Royal Society of New Zealand* (1943, pp. 97–115, 217–232, 335–350). The data for the following paper were collected during a camp of 21 weeks on the island. When perusing the literature on the whole group of which the Titi Wainui is a member one is amazed at the paucity of the material dealing with the biology of the Prions. I sincerely hope the matter which follows will add a little more to that knowledge, and that it may also serve as a stimulus to others to take up the study. In recent years the status of the various species and races has been considerably elucidated by Murphy (1936), Falla (1937 and 1940), and Fleming (1939 and 1941).

The Pre-laying Period.

It has not been possible for me to glean much information concerning this phase of the Titi Wainui's life. After the end of February, 1942, when the last chick left the island I saw no more of this species during the remainder of my stay. A gradual diminution of the Titi Wainui population commenced during January, starting with the departure of the unemployed birds and gradually followed by the disappearance of the breeding birds during February as their chicks left the burrows. This phenomenon was noted on Lady Julia Percy Island, off the south coast of Victoria, by Wood Jones (1937, p. 188), but the significance of the behaviour of unemployed birds was not realised. His party was on the island from January 10 to February 22, 1936, when it was observed that the Prions which arrived regularly during the first ten days were less regular during February, and by February 22 had ceased to arrive at all. As Wood Jones (*op. cit.*, p. 186) had already been on Lawrence Rocks on November 28, 1935, when he found a bird incubating and an unattended clean egg in another burrow, it would seem from the above two sets of evidence that the breeding times of the species off the Victorian Coast and on Whero may coincide.

While sojourning on Whero from May 10 to 17, 1941, I saw no signs of these birds, and furthermore the palisades of sticks which I had erected the previous January were still intact. Obviously the

birds had not returned though the dark nights during this week favoured their discovery had they been present. While on Herekopare, a much larger island some miles north of Whero, from May 11 to 21, 1942, and again in May, 1943, I failed to observe the presence of this species in any of the bird remains left by cats.

From August 23 to 26, 1941, when I was again on Whero, a few birds were flying about each night, though judging by the scarcity of the excreta they had not long returned to the island. Some were calling out from the air, others from the burrows, but their behaviour did not compare with the noise and activity of the previous December and January. Of the 28 nests under observation in 1940-41, 11 showed no signs of reoccupation, while 17 had been excavated. Five of the latter had a single bird in occupation at least one night during my stay. None was present in the day-time, while one of the night occupants was not an owner of the previous season. On two successive nights a ringed bird was found on the surface of the ground three yards from its burrow. In another nest containing a chick the previous January I found an addled egg which, no doubt, had been unearthed by the excavations.

In a few burrows not previously watched, an occasional single bird and pair of birds were found in the day-time, one pair occupying the burrow of a Kuaka (*Pelecanoides urinatrix*) the previous year. During this period only ten birds were caught and ringed as they landed.

On Herekopare, from August 28 to 31, 1941, they were also present, though sparsely, but the depredations of cats might possibly have accounted for their scarcity. The following year, from August 26 to 30, I was again on Herekopare. For the first three nights, owing to the full moon on the 26th, I saw no Titi Wainuis, but on the night of the 29th August it was possible to have picked up some dozens.

Just when these Prions return to the island I do not know, but I incline to the opinion that these early visits, as with *Pachyptila vittata*, are spasmodic. I gained the impression that the vast majority of the Titi Wainuis during August had no purposeful mission to pursue during their period ashore.

At different times between September 22 and November 23, 1911, when on Herekopare, Guthrie-Smith (1914, pp. 17–43) recorded several observations on Titi Wainuis. During a six hours' visit on September 22 no Titi Wainuis were found in burrows during the day-time (*op. cit.*, p. 17). On October 2 he noted that they were occupying the burrows but were without eggs (*op. cit.*, pp. 23 and 28), and that they were numerous at night (*op. cit.*, p. 25). On October 23, on a neighbouring island, Piko-mamaku-iti, he found the species in burrows, but it is not clear whether they were incubating (*op. cit.*, p. 32). Back again on Herekopare on November 23 he found many Titi Wainuis with eggs (*op. cit.*, p. 42). At the base of the same page he states that the breeding season of the Titi Wainui precedes that of the Kuaka. I do not think this is correct, for on Whero the first chicks appear very early in November (Richdale, 1943, p. 34), whereas my first record of a Titi

Wainui chick is December 18 (see Table III). Finally, Plate XIV (*op. cit.*, opp. p. 36) does not depict a Titi Wainui but a Parara (*P. vittata*).

Burrows, Incubation, and Eggs.

Generally speaking the burrows of the Titi Wainuis are found over most parts of the island. A map indicating the zones of vegetation appears in my Whero paper (1942, p. 88). In the *Stilbocarpa* areas, however, this species is rarely found nesting while in the Poa strip from the north-west corner along the north side to the middle of the east side there were no nesting birds in 1940-41. This absence may be due to the shallow nature of the soil, which makes it difficult to excavate a burrow deeply enough. In 1941-42, however, there were three nests along the north side. In the sedge just inside the Poa strip the burrows are numerous. This fact, and the occupation by Titi Wainuis of several Kuaka and Storm Petrel (*Pelagodroma marina maoriana*) burrows inclines me to the opinion that the Prions are increasing.

Most of the burrows, especially those in the *Muehlenbeckia* and sedge areas are deep, being beyond arm's length. The shallowest are round the Poa area, where one was only a hand's depth. When the chick hatched in this particular burrow its squeaking betrayed the presence of the adult to the Skua (*Catharacta skua lonnbergi*) with fatal results. Two days later the chick disappeared also.

The nesting chamber at the end of the burrow is wider than the tunnel and is usually lined, where available, with Tete-a-weka (*Olearia angustifolia*) leaves, which are stiff and narrow and about three inches long. Failing these, any handy vegetation is used.

As I did not reach the island till December 21, 1940, and December 20, 1941, when hatching was on the verge of commencing, I was unable to find out very much about the incubation period. The incubation span for each parent before change of guard is effected, from rather meagre data at eight nests, appears to be six and seven days at a stretch. Incubation for more than a week is not unusual with petrels, for I have records of 13 days for mutton-birds (*Puffinus griseus*) (1942, p. 100) and 14 days for the Royal Albatross (*Diomedea epomophora sandfordi*) (1942, p. 253), while Lockley (1942, pp. 82 and 84) notes periods of ten and nine days for two of his Manx Shearwaters (*P. p. puffinus*).

The actual time for incubation I do not know, but the following table, if my assumptions are correct, should be a reliable guide:—

Table I.

An Estimation of the Peak Hatching Date of *Pachyptila vittata* Eggs and Peak Laying Date of *P. turtur* Eggs.

Species	Laying of Eggs	Hatching of Chicks	Departure of Chicks
P. vittata	Sept. 6	Nov. 1*	Dec. 20
P. turtur	Nov. 2*	Dec. 27	Feb. 14

* Estimated peak dates.

In working out the above table the hatching dates of 85 and departure dates of 115 *P. turtur* chicks were known for the season

1941–42. All these dates from the earliest to the latest for both hatching and departure were put down in a column. Alongside each date was recorded the number of chicks that hatched or departed that day. 65, or 86·5% hatched during the 11 days from December 22 to January 1, while 96, or 83·5% departed during the 11 days from February 9 to 19 inclusive. The centre days, i.e., December 27 and February 14 in each group formed the peak periods and in fact more chicks hatched or departed on those days than on any others. The time between these two dates is 49 days. The average time worked out statistically for 66 chicks during their life in the burrow proved to be 49·35 days, so that the time arrived at by the column system is almost identical.

Now, while on Whero from August 23 to 26, 1941, I did not find any eggs of *P. vittata*, although several birds were about. On Herekopare, from August 27 to September 1, I found a few fresh ones, but the great bulk of the birds had not commenced to lay. Further, when on Whero in January, 1939, 1941, and 1942, I discovered that the remnants of the departing *vittata* chicks had all left by January 3, thus acquainting myself with the extreme limits of the egg-laying and departure of the chicks of *vittata*. Assuming that the range of laying and hatching, and being aware that the range of departure dates are the same for *vittata* as for *turtur* I was able to work out the peak hatching date of *vittata* chicks and the peak laying date of *turtur*.

Taking January 3, the known departure date of the last *vittata* chick and using the departure range of 34 *vittata* chicks as worked out in 1942–43, and allowing that the latter season was three days earlier than usual, I found by using the aforesaid column system that the peak date was December 20. Working back 49 days from this, i.e., assuming that the average time for *vittata* ashore is the same as *turtur*, November 1 is obtained as the peak hatching date. Now taking August 26 as the beginning of the laying of *vittata* and drawing up a range of dates corresponding with the range of hatching dates for *turtur*, September 6 would be the peak laying date. The assumed incubation period for *vittata* is then 56 days.

Now 56 days back from December 27, i.e., the known peak hatching for *turtur*, is November 2. It is assumed that the incubation period of both Prions is the same. Since the range of the hatching date of 85 *turtur* chicks is known and also the number of chicks hatched each day, therefore the range of the egg-laying, provided the incubation period is 56 days, extends from October 24 to November 11. Moreover, 86.5% of the eggs will be laid between October 28 and November 7, a period of 11 days.

The statements of other observers may be compared with the above estimates of the laying dates of the Titi Wainui. Stead (1942, p. 5), when referring to Green Island which is 16 miles north-east of Whero (Richdale, 1942, map, p. 86), states that Titi Wainuis begin laying in the second week in November. It has already been stated that Guthrie-Smith found Titi Wainuis incubating on November 23 and that it could not be certain if this were so for October 23 (see p. 33). Fleming (1941, p. 147) quotes mid-October as the

commencement of the laying period. The information given by Falla (1934, p. 248) regarding breeding dates off the Auckland east coast area seems to indicate that the period coincides with that on Whero. Buddle's evidence (1941, p. 60), however, is different and shows quite clearly that the latter group breeds earlier. He was on the Poor Knights from November 24 to December 2, 1941, this being the same season that I began serious work on Whero. He records that by the last week of November all eggs had hatched and chicks in the first down ranged from a few days to perhaps 10 days old. On Whero the limits of my 29 hatching records that year were December 22 and January 8 (table III). In 1942–43, the first of 78 chicks under observation did not hatch till December 24 and the last on January 15. In summing up, it will be observed that all records, with the exception of Buddle's, approximate to mine.

In colour the eggs are white and there is considerable variation in size and shape. As I mentioned in my Kuaka pāper (1943, p. 29), some of the small eggs are very difficult to distinguish from the large eggs of the Kuaka. The largest egg measured was 48¼ x 34½ mm. while the smallest were 41½ x 30½, 42¾ x 29, and 41½ x 30 mm. The weights were taken from eggs in all stages of incubation and one or two were addled.

TABLE II.

Measurements of 100 Eggs and Weights of 56 Titi Wainui Eggs Taken on Whero.

Feature	Mean	σ	PE_m	Range
Length	45.12 mm.	1.61 mm.	.11	40½ to 48½
Width	32.64 mm.	.99 mm.	.06	29 to 34½
Weight	24.2 gms.	2.61 gms.	.24	18¼ to 29¼

When the egg is finally deserted, one or both birds occupy the burrow for a few nights before leaving the island entirely for that season. Frequently, though not always, the egg is scratched out of the burrow during these operations. Desertion with the Storm Petrel is followed by the return of the birds for a time after having had a spell at sea.

I found a considerable number of deserted eggs, many of them on the surface of the ground. Old addled eggs were also discovered in the burrows. In 1940–41, the birds at nest 7 deserted their egg. Next year the same pair was back sitting on an egg laid that season and were also covering the old one alongside. The second egg hatched.

HATCHING.

To my knowledge the first hatching of a Titi Wainui chick during my visits to Whero must have occurred on December 18, 1941. In my first season 50 nests were found with eggs, while in the second there were at least 98 either with eggs or young chicks. The age of the latter was easily determined when the down or feathers reached one of the stages shown in table IV. Below is given a table of the hatching dates grouped into two-day intervals for the two seasons separately of all the chicks I found. Some of the eggs for various reasons did not hatch.

TABLE III.

Hatching Dates of 104 Chicks Placed in Class Intervals of Two Days.

Dates of Class Intervals	No. of Hatchings 1940-41	1941-42	Total
Dec. 18–19		1	1
Dec. 20–21		2	2
Dec. 22–23	1	7	8
Dec. 24–25	3	13	16
Dec. 26–27	3	22	25
Dec. 28–29	6	16	22
Dec. 30–31	7	6	13
Jan. 1–2	6	3	9
Jan. 3–4		4	4
Jan. 5–6	2	1	3
Jan. 7–8	1		1

It will be noticed that in 1940–41 the hatching period ranged from December 23 to January 7, while in 1941–42 it was from December 18 to January 5. The total range of 20 days for 104 hatchings shows a restricted laying period. There seems to be a tendency in the latter season for a slightly earlier laying, which feature is far more pronounced in the Kuakas (Richdale, 1943, p.34). The peak hatching period extended from December 25 to 30, inclusive, when 63·5% of the chicks appeared.

Though it is difficult to ascertain just when the shell is first chipped, close observation on several eggs indicated that after chipping the chick took at least two full days to emerge. At one nest at 10 a.m. on December 28, 1940, a chick could be heard calling through a slight crack in the shell, but there was no hole. Next morning the chick, though still calling, seemed to have made no further progress. On the morning of December 30 there was a small hole in the shell, which by 4 p.m. had increased to about the size of threepence. By 8.30 p.m. the chick, still calling, with its eyes closed, had just hatched and was wet. The final exit is always sudden and in this case the whole process took almost 2½ days.

Events at this same nest which was found on December 28 with No. 32 parent in charge are probably worth relating as being typical of events just before and after hatching. Next day the same bird was still there but the palisade of sticks which I had placed across the burrow on the previous day was flattened and facing in, indicating that another bird must have entered. Could it have been the other parent? I do not think so, for I have every reason to believe that when a parent returns it always changes guard. It is quite likely that a wandering unemployed Titi Wainui entered the burrow. I have several instances on record where this class of bird has entered Kuaka and Storm Petrel burrows when occupied by the owners. On December 30 the sticks were again pushed in and 32 was still in charge. The wet chick at 8.30 p.m. weighed 16 grams, while 12 hours later, at 8.30 a.m. on December 31, it weighed 18½ grams, indicating that it had been fed; this time No. 15 was on guard. On January 1 a parent was present all day, but I did not identify it. The following day the chick was alone, but on January 3 there was a parent present all day; this being the last occasion on which this chick was guarded during the day. At 9 p.m. on December 31, the chick, weighing 16

grams, showed a drop of 2½ grams so that it was probably not fed during the day. At 9 a.m. next day, however, it was 28½ grams, an enormous meal for so young a chick.

After hatching, the chick takes some time to dry. At 5.10 p.m. at one nest the chick was still wet, showing slight signs of drying on the tips of the down, and the cord was gone. Its weight of 18½ grams made me suspect it had been fed; it defecated watery matter. Later on the same day at 8.45 p.m. it was nearly fluffy, though the down was still somewhat knotty. As it weighed 20 grams it had been fed since 5.10 p.m.

When the chick has emerged the egg shell is usually removed from the nest and is frequently found in the mouth of the burrow. I believe, too, that the chicks are hatched bright-eyed, for several of them opened their eyes when handled within the first 24 hours, but shut them again immediately. The excreta when the nestling is a day old contain something which looks like oil and some black material.

Eggs are sometimes hatched after they have been left cold for at least one day when incubation is far advanced. Two such cases occurred in 1941–42, but I did not determine the length of time of desertion. On December 26 both eggs were cold and unattended and when I next inspected the nests on January 3 both had chicks which were hatched the previous day. These two chicks completed the full life cycle in the burrow and then flew. At a third nest on December 25, 1940, No. 21 adult was covering an egg which I found deserted and cold the next day. On December 27 the egg was guarded by No. 10 adult, but in spite of this desertion the egg hatched on January 6.

The Chick.

As already stated the earliest chicks begin to hatch between December 18 and 21 and are covered with long medium violet grey down (40g*), 20 mm. long on the body and 10 mm. on the head; the weight is between 16 and 18 grams. The eyes, though hidden by the long down, I think are open at hatching, certainly very soon afterwards. The tip of the beak can be just seen protruding through the down, the youngster squeaks quite freely, and if the fingers are placed over the bill it performs feeding actions. The bare parts of the leg are dark blue (19d*) all over, except the webs which are a faint reddish violet (23u*), but all are obscured by the down. The chick resembles a beautiful fluffy powder puff (Plate 10, Fig. 1). Another feature at this stage is the manner in which the hand, covered with very short protoptyle protrudes beyond the long down of the rest of the body.

Growth is very rapid, and some of the large meals given, occasionally equal the weight of the chick. The parents soon leave their offspring, sometimes on the morning after the night it is hatched, though an attendance of two days immediately after hatching is more usual. On the seventh day the mesoptyle may be clearly seen through the skin on the scapulars to cover the whole body completely in the space of a few days, while at the beginning of the second week the

* The key to these colour numbers is given at the end of this part.

eyes are plainly visible through the long down of the forehead. Biting quite freely, chattering a great deal, the chick is a very agile little creature. The protoptyle loosens up considerably as the skin area increases and the mesoptyle grows. During its life in the burrow the various parts of the bill change considerably. Between the age of nine and 15 days the egg tooth slowly wears and falls off, this phenomenon varying greatly in different chicks. The number of chicks under study for this purpose was eight, and the average time proved to be the 13th day.

At the beginning of the third week the chick begins to develop feather quills on the scapulars, forearm, and the hand. On the eighteenth day the tail quills are pushing through, otherwise there is little outward change, except in bulk.

During the fourth week the most pronounced feature is the rapid growth of the long feathers of the wing and tail. The primaries reach a little over 30 mm. in length.

When 28 days old the chick is probably at its most beautiful stage, with its three coats of feathers practically intact. No outward sign of the teleoptyle is visible, though when the down is parted it can be plainly seen. Through the down of the body it is just possible to distinguish the tail feathers and the primaries. The bill having become elongated resembles that of the adult. Though hidden, the hand is practically free of down. Chicks that have been handled are very tame and playful. Others bite hard and have both raucous and canary-like calls.

At 36 days the chick still retains its fluffy appearance but the down is very loose and beginning to come off quickly. Most of the protoptyle is gone and when compared with a younger chick it is much lighter in colour. The mesoptyle on the forehead is rapidly disappearing and fairly closely grown feathers have filled up the bare patches round the base of the bill, gape, and eyes. As these feathers are white it gives the chick a characteristic appearance.

On the 43rd day, though still covered in a thin coating of down, the time is fast approaching when it will emerge as a fully-fledged chick. 60 mm. of the primaries and secondaries and 30 mm. of the tail are now clear, and free of down. The head and neck can be seen to be very well covered through the thin down. In fact, at this stage, the appearance of the chick is very like that of the adult.

During the next and final week the down suddenly disappears, as it were, overnight, and the chick emerges fully-fledged, perhaps with slight traces of down.

After a preliminary study on nine chicks in 1940-41 to discover the appearance of the several groups of features mentioned in the table below, I watched a further eight chicks in 1941-42 to check up my results. The measurements of the growth of the primaries were taken from one chick only.

In the table below is given an abbreviated list of data which could be utilised by other workers to enable them to estimate the age of Titi Wainui chicks found on islands they may visit. Instead of using such terms as " well-grown chicks " which are most unsatisfactory, the noting of some feature mentioned below should permit of a far more accurate comparison being made.

TABLE IV.

Data for Estimating Age of Titi Wainui Chicks.

Age in Days	Remarks
7th	Mesoptyle on scapulars appears
8th	Mesoptyle on forearm appears
9th	Mesoptyle on hand appears
14th	Feather quills on scapulars appear
15th	Feather quills on forearm appear
16th	Feather quills on hand appear
18th	Feather quills on tail appear
10th to 16th	Egg tooth goes, average on 13th day
17th	Length of longest primary, 3½ mm.
19th	Length of longest primary, 10 mm.
21st	Length of longest primary, 15 mm.
23rd	Length of longest primary, 19 mm.
25th	Length of longest primary, 24 mm.
27th	Length of longest primary, 30 mm.
31st	Length of longest primary, 40 mm.
35th	Length of longest primary, 61 mm.
39th	Length of longest primary, 80 mm.
43rd	Length of longest primary, 97 mm.
47th	Length of longest primary, 110 mm.

Different observers will no doubt arrive at different results from what I have given in the above table due to the difficulty in seeing and deciding when the feathers appear. It would be quite easy to overlook their appearance for some days. My method of measuring the primaries is to take the longest primary near the tip and measure on top of it with dividers. As soon as the third primary from the end can be definitely fixed this is chosen for measurement. With the growth of the feathers measuring along the top is obstructed so it is then necessary to measure under the wing.

The chicks at no stage cough up oil as is the case with the Storm Petrel, Mutton-bird, and Royal Albatross.

The behaviour of the Titi Wainui chicks after frequent handling is somewhat reminiscent of the Royal Albatross chick which becomes quite tame and playful. As early as January 2, No. 29 chick, then 29 days old, was quite lively with a bright look in its eyes. Besides biting playfully at my hand it would wave its wings, clamber about, sleep, bite and nibble at parasites, and not jump to the touch when handled. A week of two later when being described on the table it pulled, tugged and played with the cloth on which it was sitting. On January 20, I found for the first time an old chick which soon transformed from being wild and timid into a quiet and playful creature, and was a great favourite. The Kuaka chicks, on the other hand, never became playful, but when half-grown, constantly emitted a very mournful note when handled.

As regards external parasites Titi Wainui chicks tend to be much infested with fleas, especially if the burrows are dry. Attacking weak chicks in particular, they crowd round the eyes and face of the victim. Ticks, usually attached to the feet, but sometimes on the head and round the eyes, also molest the chicks; feather lice, too, are common, and these are also found on the adults.

Mortality among the chicks in 1940–41, which was a good, dry season, did not appear to be very great. Four of the 25 chicks under observation died. One succumbed owing to an excessively wet burrow, another from starvation as a Skua ate the parent, a third which was in a very shallow burrow probably also fell a victim to a Skua, and a fourth died from unknown reasons.

In 1941–42, also a dry season, of the 76 chicks that were under observation in burrows during their whole period ashore, only six did not leave the island. All of these, for some reason unknown to me, either died in the burrow or disappeared during the first two weeks. None of these chicks died when older than two weeks.

PARENT AND CHICK.

In this section some observations concerning the interesting relations of parent and chick will be discussed. Parents spend very little time with their chicks in daylight hours, during which period they are sometimes fed. Table V deals with observations taken in 1940–41 only.

TABLE V.

Appearance of Adult with Chick in Early Stages.

Age of Chick in Days	Parent in Charge					
	Nest 22	Nest 29	Nest 8	Nest 9	Nest 12	Nest 12a
1st	No. 2 HE	No. 22 HE	No. 31 HE	No. 33 HE	No. 36 HE	No. 34 HE
2nd	No. 6 ?	No. 22 FN NFD	No. 31 FN FD	No. 15 FN NFD	No. 36 FN FD	No. 34 FN NFD
3rd	None NFN	None FN	None NFD	No. 33 FN NFN	None FN	None NFN
4th	No. 6 FN FD	No. 22 FN NFD	No. 32 FN FD		No. 36 FN FD	No. 34 FN NFD
5th		None FN			No. 33 FN FD	None FN
6th		No. 8 FN FD				No. 34 FN NFD
7th						None NFN
8th						No. 35 FN NFD

Key.—HE, hatched that evening; FN, fed during previous night; NFN, not fed during previous night; FD, fed during day; NFD, not fed during day.

In the foregoing table is given the occurrence of the parent with the chick in the daytime during its first few days of life. After the occasions listed in the table the parent was never found again with a chick during the day. It will be noticed in all cases that the chick was hatched late in the day, the earliest being that at No. 9 nest, which appeared just before 8.30 p.m. In all the examples given the chick was fed presumably by the parent in charge before 9 o'clock next morning, while in two cases out of five it was fed during the day as well. My method of discovering these facts as well as others

was to weigh the chicks at 9 a.m. and 9 p.m. during their period in the burrow. On the second day, i.e., the day after hatching, a parent brooded each chick, but on the third day all but one had been left alone. On the fourth day the five that had been deserted the previous day were brooded while the sixth chick was alone. After this only some nests had parents in attendance again during the day. In three nests the parents were there twice during the day, in two cases three times, and in one case four times. This was the procedure in a number of other nests where the chicks were not weighed.

Feeding usually occurred at night and occasionally in the daytime. If the chick remained unfed at night it was a sign that the second bird had not come home and that the first had to leave without feeding. The chick at nest 12a was fed on the night preceding the sixth day, but not on that day, although a parent was present. On the night preceding the seventh day it was not fed, and by 9 p.m. that day had dropped to 18 grams. At 9 a.m. on the eighth day it had risen to 36½ grams, i.e., double its weight, and though the parent stayed with it, no food was transferred that day. Even so, its weight was lighter than the other five chicks taken on the eighth day.

It will be observed that the parents stayed with their chicks for a total of from three to five days and that these attendances were spread over from four to eight days. In every case noted, each parent brooded the chick during the day at least once. At nests 12, 29, and 12a it was not till the fifth, sixth, and eighth day respectively that the chick was brooded by the second bird. After that period it was not attended again. It would appear that each parent wishes to feel the presence of the chick beneath it before abandoning it during the daytime. Only once, at nest 12, did the first bird to brood a chick return to perform that operation after its mate had had a turn.

In 1941–42, when weighing a number of chicks twice daily from the age of 28 days until they flew, together with many more during their last 10 days ashore, I never once found an adult with the chick in the daytime. With the Storm Petrels and the Kuakas, however, there were occasional exceptions to this rule.

That parents are rarely found together with their chicks at night is amply demonstrated by the following activities. During the 1941–42 season the various nests were visited nightly till all the parents were ringed. On 102 occasions I found and ringed a single bird, while on many other unrecorded occasions while still searching for the second bird I again came across the first bird ringed. Having once ringed the second bird I did not search the burrow again. Only three times when making these visits were two birds found together in the burrow at night. This behaviour is similar to that of the Storm Petrel, but in great contrast to the Kuaka which is usually found in the burrow in pairs at the chick stage. With unemployed Titi Wainuis, however, a pair was found together far more often at night.

My earliest record of a parent's homecoming is 10.45 p.m., about 15 minutes after complete darkness in summer in this latitude. Round 11 p.m. many of them arrive and till midnight many more. My method of watching was to place sticks across the burrows, re-

turning to make observations at frequent intervals during the night. At nest 8 on the night of January 27. the sticks had not been moved by 12.30 a.m., but in the morning the chick had advanced the record weight of 56 grams from 80 to 136 grams, so that probably two birds came in after 12.30 a.m. By 2.30 a.m. at the latest they would be gone. There is evidence, as shown by the removal of the sticks, that some of the parents at least do not stay more than 15 minutes. At another nest on the night of January 15 the sticks were not moved till after 1 a.m., and on this occasion 33 grams were given, so that it appears as if the birds may come in any time during the night. This particular night, however, it was just past full moon and the weather was squally at times. On two occasions, both on moonlight nights, I saw No. 4 parent fall through the Tete-a-weka trees some six feet from the nest and scuttle away immediately into its burrow which, situated as it was in bare ground under the trees, enabled me to watch the bird's behaviour clearly. From the air, the similarity presented by the canopy of trees makes this feat of falling through in close proximity to the burrow rather remarkable.

Both parents must feed the chicks on some nights as is probably indicated by the heavy meals. This was proved by means of sticks placed across the burrow at night; by keeping watch every 10 minutes or so I noted when a bird entered. If, after the sticks were replaced they were again pushed in, it probably indicated, unless there was an unemployed bird on the prowl, that the second parent had entered. On one such occasion a bird was ringed in a burrow at 10.45 p.m. on January 28, and at 11.15 p.m. a second bird was found with the chick.

I had been endeavouring for some time to watch an adult feed the chick, and one night at 11.15 p.m., noticing the sticks down at nest 22, I removed the plug and saw the adult sitting in the tunnel leading to the nest. The chick was asleep, apparently not aware of the adult's presence. Later it moved up to the chick which squeaked a little—just a few faint squeaks—a call with which I was not familiar. It was difficult to follow the feeding; the chick was higher up than the adult and the heavy down blocked my view. After a slight cough the adult appeared to open its beak, while the chick seemed to put its bill right in, pull it out, raise it and then swallow. As far as I could judge the method bore a close resemblance to that employed by the Kuaka. Subsequent attempts to watch on succeeding nights were less successful and I had to abandon the task.

FOOD AND RELATED TOPICS.

As the species under consideration frequently regurgitates its food when handled, samples for examination were easily obtained. In all cases they were found to contain a mass of Euphausids about half an inch long.

In table VI is given the hatching dates of eight chicks in the 1940–41 season weighed twice daily up to January 30, and of ten chicks in 1941–42 weighed from January 26 till they left the island. The quantity of food received each night was determined by the difference between the evening and the following morning weights. Nights on which chicks were not fed are also noted. Weights in-

dicated by an asterisk represent the amount of food given by a guarding parent during the day, and this occurs several times the first few days. The amount of food as shown by the table varies from 0 to 56 grams, but it must be remembered that these weights, owing to the method used, will be slightly less than the actual weights.

TABLE VI.

Nights Fed and Amount of Food Given to 8 Chicks in 1940-41 and 10 in 1941-42.

Chick	Hatched	Dec., 1940 24	25	26	27	28	29	30	31	Jan., 1941 1	2	3
	Dec. 1940	gm..										
		2*		4*								
22	23		NF	12	NF	NF	11½	20	9½	31½	NF	NF
								3½*		1½*		
8	29							3½	NF	8½	−1½	12½
9	30								2½	12½	0	11
							2½*		5½*	5*		
12	28						3	1½	8½	3	2½	18½
12a	29							3½	NF	10	½	11½
							2½*					
29	24		3½	2½	8	0	10½	NF	12½	13	13	12
4	25						NF	12½	7	19	NF	12½

TABLE VI (Continued).

Chick	Jan., 1941 4	5	6	7	8	9	10	11	12	13†	14	15	16
22	25	15	30	4	10	NF	32½	NF	18½	15	21½	19	17
8	4½	9½	16½	15½	22	NF	18½	3	10½	16	6½	15	15½
9	4	8½	14½	8	23½	18½	13	NF	13½	19	12	15½	11½
12	19½	12	7½	8	15	NF	28½	21½	28½	4	12½	12½	8
12a	NF	18½	4½	17	17½	5	14	NF	12	12	8	26½	5½
29	6	12½	24	17	10	NF	20	14	6	33½	3	NF	17½
4	2	NF	14½	8½	28	NF	22½	16	3½	11½	7	12½	32

TABLE VI (Continued).

Chick	Jan., 1941 17	18	19	20	21	22	23	24	25	26	27	28	29	30
22	13	14	22	NF	16	9	NF	13	4	26	16	6	8	13
8	19	9½	18½	2½	10	5½	40	2	NF	NF	56	18	40	10
9	45½	15	27	11½	8	33	NF	41	30	NF	37	5	15	NF
12	11½	12	12	8	5	10	NF	13	NF	34	28	NF	39	NF
12a	20	4½	10½	14½	11½	NF	NF	23½	5	19	6	13	4	NF
29	15	27½	NF	6	18	4	NF	10	8	7	7	15	NF	31
4	12	NF	NF	23	25	11	24	3	NF	NF	16	11	18	32
56	(Dec. 18)				12	34	NF	16	6	NF	9	NF	41	20

TABLE VI (Continued).

Chick	Hatched Dec., 1941	Jan., 1942 26	27	28	29	30	31	Feb., 1942 1†	2	3	4	5
3R	28	12	5	0	10	15	7	11	8	21	37	43
7R	26	20	10	20	13	NF	NF	5	9	17	16	16
22	27	19	NF	10	NF	15	43	0	−6	NF	NF	33
4	27	NF	18	44	30	NF	18	7	24	39	24	NF
5	28	7	11	20	4	5	27	3	7	4	2	13
12R	27	26	NF	NF	NF	12	36	9	25	26	NF	NF
lbs	22	33	14	10	NF	15	24	11	37	15	5	28
22R	22	12	16	14	8	9	22	NF	18	12	4	11
24R	28		10	35	33	NF	NF	4	24	35	−4	7
25	29		17	17	9	51	NF	0	9	15	34	33

TABLE VI (Continued).

Chick	Feb. 6	7	8	9	10	11	12	13	14	15	16	17	18
3R	5	–3	6	5	NF	NF	NF	NF					
7R	4	20	23	11	15	7	5	NF	22	NF	13	17	NF
22	51	17	4	0	NF	NF							
4	44	12	NF	11	0	24	–2	NF	NF	NF			
5	13	11	11	NF	9	19	–1	26	NF	NF			
12R	44	25	24	NF	NF	NF	11	19	NF	NF			
lbs	NF	NF	NF										
22R	NF	NF	NF	NF									
24R	24	7	NF	NF	25	8	4	11	5	0	0	–2	NF
25	15	NF	NF	20	NF	6	14	25	1	–1	NF	NF	NF

* Means amount of food given to chick during the day by a guarding parent.
† Means full moon.
NF Means not fed during night.
– i.e., a minus sign prefixed to a figure indicates that the morning weight was less than the previous evening weight.

TABLE VII.
Weights of 455 Meals Given to 17 Titi Wainui Chicks, Grouped into Class Intervals of 10 Grams.

Class Interval	No. of Meals	Percentage
No meal	102	22.4
0 to 9.9 gms.	124	27.2
10 to 19.9 gms.	141	31
20 to 29.9 gms.	50	11
30 to 39.9 gms.	25	5.5
40 to 49.9 gms.	10	2.2
50 to 59.9 gms.	3	.7

The data for the above table were compiled by weighing seven chicks from hatching to January 30, 1941, and a further ten from the age of 28 days to their departure in February, 1942. In addition to this 65 chicks were weighed during their last ten days or so ashore. It will be noted from the table that slightly over 75% of the meals given ranged between 0 and 19·9 grams.

The following table deals with two sets of chicks already enumerated. From a perusal of Tables VI and VIII it will be seen that the number of times a chick is not fed is considerable, and this phenomenon occurred in both seasons. The range in 1940–41 varied from 12·5 to 23·7%, and in 1941–42 from 14·3 to 47·6%. If the final days not fed after the last meals ashore are excluded the range is 0 to 42·1%. For both years the average is 22·75%, but if the final nights not fed are excluded it is 16·7%. In other words, while parents are feeding their chicks they omit to feed them on 16·7% of the nights; with Storm Petrels the percentage is 28·4.

The average amount of food given per meal varied in the first year from 11·4 to 16·8 grams, and in the second (in this year they were older) from 10·4 to 23·4 grams. The case of the chick at 12R is interesting. At the end of its period ashore it was weighed on 21 occasions, yet it was unfed 10 times. Its total quantity of food received was the third greatest of all the chicks that year and its

TABLE VIII.

Data Relative to the Irregularity of the Feeding Process.

	Nights When Not Fed						Quantity of Food Received			
Nest	Days in Burrow	Amount of Down at Departure	No. of Times Not Fed	DNF*	No. of Days Weighed	% of Days Not Fed	No. of Nights When Fed	Amount Received in gms.	Average in gms. for Each Night Fed	Average per Day in gms.
	1940-41									
22			9		38	23.7	29	467	16.1	12.4
8			4		32	12.5	28	415	14.8	13
9			4		31	12.9	27	455½	16.8	14.7
12			5		33	15.1	28	388	13.9	11.8
12a			6		32	18.7	26	297½	11.4	9.6
29			7		37	18.9	30	389½	13	10.5
4			7		33	21.2	26	407	15.7	12.4
	1941-42									
3R	47	T	4	4	19	21 (0)**	17	182	10.7	9.6
7R	55	T	6	3	25	24 (13.6)	19	263	13.8	10.5
22	46	T	6	2	17	35.3 (26.6)	11	186	17	11
4	50	T	7	3	21	33.3 (22.2)	14	293	21	14
5	49	ND	3	2	21	14.3 (5.3)	18	187	10.4	9
12R	50	ND	10	2	21	47.6 (42.1)	11	257	23.4	12.2
11s	48	T	4	3	14	28.6 (9.1)	10	192	19.2	13.7
22R	49	T	5	4	15	33.3 (9.1)	10	126	12.6	8.4
24R	52	T	5	1	23	21.7 (18.2)	18	226	12.5	9.8
25	51	T	7	3	23	30.4 (20)	16	265	16.6	11.6

* Means days not fed after last meal ashore (included in previous column).

** Means percentage of nights not fed when days not fed after last meal ashore are excluded.

T Means trace of down.

ND Means no down for 1 day before leaving.

average amount per meal was the highest. The other two chicks which missed many nights, i.e., seven, also record the highest aggregates of food. It would seem, therefore, that missing meals is no hardship, the large quantities per meal amply compensating for the omitted feedings.

When, however, the total amount of food received is divided by the total number of weighings, including the nights unfed, it will be noted, as shown in table VIII that there is a tendency for the amounts to level up. For example, chick 12R which received the greatest average amount (23·4 grams) per meal when fed was

only third in the list when the total weighings were divided into the total amount of food received. When compared with the Storm Petrel (Richdale, 1943, p. 221) this levelling process is by no means so striking and uniform.

Grouping all chicks together and excluding the days when chicks were not fed after their last meal ashore there were 41 occasions on which they missed a meal for one night only, 11 occasions when there was a span of two nights, and only twice a span of three days. The two spans of three days missed were experienced by chick 12R which averaged the highest quantity per meal.

Some of the weight increases of the different chicks not already given are worthy of note. Chick 22 (1940–41) when nine days old weighed 39 grams at 9 p.m., and next morning it was 70½ grams. On the following two mornings it dropped to 46 and 38 grams respectively without being fed, so that evidently chicks can accommodate a large meal and fast, if necessary, for a short time. On its third evening of life this same chick weighed 17½ grams and next morning was 29½ grams, an increase of 12 grams which, is a huge proportion.

Still another chick, No. 8, which, to my knowledge, accommodated the largest amount of food (56 grams at 30 days old), advanced, on the morning when 26 days old, 40 grams, which was more than double its previous highest of 19 grams. Next day, having acquired overnight, a light meal of only two grams, it dropped from 134 to 123 grams. On the following two days it had dropped to 97 and 85 grams respectively without receiving any food, and on the final afternoon it was down to 80 grams. On the 30th day it rose sharply to 136 grams, having received, as I mentioned earlier, the enormous meal of 56 grams. By the 32nd day, after another meal of 40 grams, it reached 172 grams, this figure representing the heaviest weight I had for any of the seven chicks. Daytime meals were never very large, the highest being only 5½ grams.

TABLE IX.
Average Weight and Number of Meals Given Daily to 7 Titi Wainui Chicks in 1940-41 and 10 in 1941-42, Grouped into Class Intervals of Four Days.

Class Interval in days	No. of Meals	Avge. Weight in grms.	Class Interval in days	No. of Meals	Avge. Weight in gms.
1– 4	15	6.57	29–32	42	17.43
5– 8	23	10.43	33–36	43	15.35
9–12	23	13.17	37–40	41	18.17
13–16	25	16.6	41–44	33	16.91
17–20	24	15.2	45–48	22	11.32
21–24	27	14.68	49–52	6	5.33
25–28	19	17.07			

To construct table IX the nightly meals were put down in columns according to the age of the 17 chicks concerned. Thus the first column recorded the weight in grams of the food received by each chick on the first day after the hatching; the second column the amount received by each on the next, and so on. These columns were then grouped into four, the totals of each set of four columns found and divided by the number of nights when feeding occurred. I could not estimate the average of each four columns owing to the number of times when feeding was omitted.

TABLE X.

Average Weights of Meals Given to Titi Wainui Chicks at Various Periods.

Occasion When Weights Taken	No. of Cases	Avge. in gms.
After missing 1 meal	42	18.2
After missing 2 meals	11	24.54
After missing 3 meals	2	11.5
1st meal after a fast	56	19.1
2nd meal after a fast	44	15.5
3rd meal after a fast	39	16.1
4th meal after a fast	30	15.7
5th meal after a fast	25	11.5
6th meal after a fast	9	19.3

The above table has been made out to check up to what extent, if any, the average weights of food given, are influenced by periods of fast and by successive meals. The top part of the table would seem to indicate that heavier meals are given after two nights of fast than after one. To show the effect of longer fasts I have not sufficient data. Meals after fast periods seem to be larger than at ordinary times. As regards successive meals after a fast of any length the second, third, and fourth are much the same and are all lower than the first meal after a fast. The weight of the fifth meal drops considerably and probably after that rises again, but the data I have with regard to it is meagre.

NOTE.

In the section on the chick, colour numbers and letters as found in Radde's Colour Chart are used. A list of the colours referred to in the text with their respective numbers appears below. The darkest shade of each colour is given the letter "a" and the lightest the letter "v".

19.—Blau.
23.—Violet, Erster Uebergang nach Purpur.
40.—Violetgrau.

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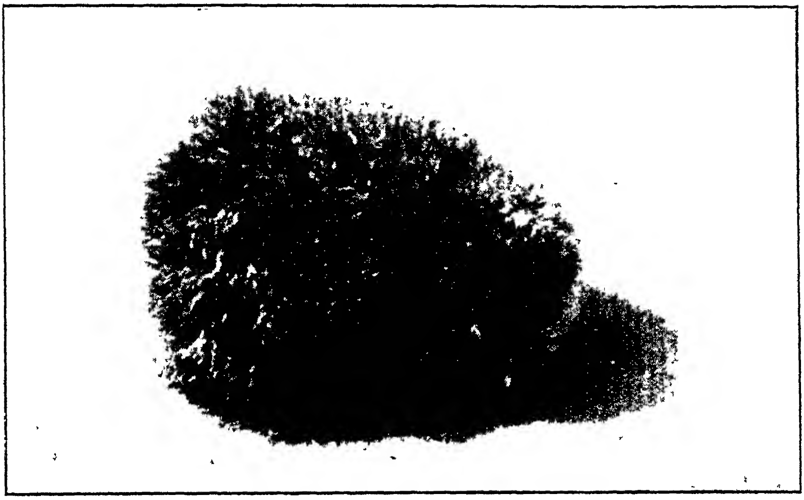

Fig. 1.—Titi Wainui Chick, Two Days Old, 25/12/40. Note Egg Tooth on Tip of Bill.

Fig. 2.—Adult Titi Wainui, 18/12/38.

Facing page 48.]

Vol. 74, Part I, pp. 49–70, Plates 11–13.

Geology of the Southern Waitakere Hills Region West of Auckland City.

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[*Read before Auckland Institute, September 15, 1943; received by the Editor, September 27, 1943; issued separately, June, 1944.*]

Abstract.—A short account is given of the geology of a region west of Auckland composed mainly of the Tertiary volcanic Manukau Breccias of the southern half of Waitakere Range. These are underlain conformably on their east by sediments of the Tertiary Waitemata Series which are covered locally by Pleistocene clays. The writer deals also with the petrography and origin of the Manukau Breccias and of clastic dykes that they include.

INTRODUCTION.

This outline of the geology of the southern portion of the Waitakere Hills, west of Auckland City, is based on reconnaissance work carried out 10 years ago under the guidance of Professor J. A. Bartrum and submitted as a thesis for the Master's degree. No survey of the geology of the whole area had previously been attempted, although from the earliest days of New Zealand geology parts of the region, notably between Onehunga and Manukau North Head, have received attention, particularly from Hochstetter (1864) and Hutton (1870). Other writers on limited aspects of the geology have been Smith (1881), Cox (1881, 1884), Park (1886, 1889), Fox (1902), Mulgan (1902) and Bartrum (1923, 1926, 1937).

GENERAL DESCRIPTION OF AREA.

The Waitakere Range, which constitutes most of the region described, is a plateau composed essentially of fragmental volcanic rocks, which has a general elevation of about 1100 feet, but is surmounted by occasional peaks of which Te Torokawharu (1506 feet), north-west of Huia Bay, Manukau Harbour, is the highest according to Mr. A. D. Mead, Waterworks Engineer, Auckland City Council*. Vigorous short streams have carved characteristic precipice-walled deep gorges, causing very strong relief, and have very steep courses, often with falls as much as 80 feet in height. A canyon in the lower course of Piha Stream on the west coast is a remarkable cleft, maintaining a width of only 11 feet for a height of 200 feet above the stream bed before widening. The larger streams wander on wide alluvial flats between steep valley walls near their mouths; this clearly is a result of the recent submergence that is so well exemplified throughout most parts of Auckland Province.

Dykes and inextensive thin flows vary the general fragmental material, but rarely affect the longitudinal profiles of the streams; thick pillow lavas furnish an exception, however, and give rise to falls at the head of the lake impounded by Nihotupu Dam.

The east face of Waitakere Range descends very abruptly to lowlands along a line running approximately north from Puponga Point, a tongue-like promontory on the north coast of Manukau Harbour; this scarp appears not to be due to faulting but to sudden change in the resistance to erosion of the rocks concerned, for east

of the line mentioned the resistant volcanic rocks are replaced by soft sediments of Tertiary and later age. The drainage is insequent both in the western highlands and the eastern lowland region, for in this latter the structure is confused, so that, although there is some variation of hardness in the Tertiary rocks, no directional control of stream direction has been possible. The streams of this eastern region are gently graded and notably in the case of Whau Stream end in lengthy tidal creeks in consequence of the recent submergence noted above.

Along the west coast the powerful waves of Tasman Sea have eroded seacliffs usually many hundreds of feet in height, although over a considerable portion of this length of coastline the bases of these cliffs are protected by beach and wind-blown sands.

A remarkable feature of the local geology is the abrupt southern termination of Waitakere Range and its replacement by the waters of Manukau Harbour and its fringing low flats; these latter are underlain by Pleistocene silts capped locally by the products of basaltic eruptions and pass west into a highly elevated range of poorly consolidated Pleistocene dune and other sands (Gilbert, 1921). Hochstetter (1867) ascribes this abrupt transition to the presence of a north-east—south-west fault margining the northern shore of Manukau Harbour and its existence is also accepted on considerations of broad regional structure by Bartrum (1937); it cannot be traced, however, beyond the narrow isthmus that separates west from east coast sea waters about three miles east of Onehunga. It had long been believed that the volcanic rocks of Waitakere Range terminate at this fault, but Mr. C. W. Firth† recently has found that they outcrop at sea level at Clark's Beach and Te Tóro on the southern shores of Manukau Harbour, 10 miles south of their nearest northern outcrop.

Topography.

As will be shown later, the deposition of the volcanic mass of the Waitakere Hills followed closely upon that of the Tertiary (Waitemata Series) sediments further east. Broadly considered these hills are a one-cycle range that owes its elevation above adjacent lowlands to the superior hardness of its materials. Nothing need be added to what already has been stated about the topography of this highland, but it is different for the eastern lowlands, for these show erosion levels comparable with those of the Silverdale-Takapuna area described by Turner and Bartrum (1929) and indicative of discontinuous uplift.

The highest of these erosion levels is a much dissected surface about 600 feet above sea level near Titirangi and north from there fringing the steep face of Waitakere Range; it is part of the dissected peneplain of Auckland recognised by Cotton (1922) and Bartrum (1923) and is a product of the widespread late-Tertiary peneplanation that has been recorded by various writers from many parts of North Island, as, for example, Bell and Clarke (Whangaroa, 1909), Grange (North Taranaki-South Auckland, 1927), Bartrum and Turner (North Cape, 1928) and Ongley and Macpherson (near East

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* Personal communication.

† Personal communication to Professor Bartrum.

Cape, 1928). Benson (1935) has discussed the relation of the peneplanation of this date to that of Cretaceous age in southern New Zealand. If, as appears to be the case, Pliocene rocks of the Wanganui-Rangitikei basins have been truncated during this period of erosion, its date cannot be earlier than later Pliocene.

Other erosion levels include one at 350 feet above sea level which is well displayed near Oratia, two miles west of Glen Eden, and another at about 120 feet which is prominent on the shores of the harbour at Auckland. The most striking erosion level of the present area, however, is in the New Lynn-Point Chevalier district and varies in elevation from 40 feet to 60 feet above sea level. It has its maximum extension in a peninsula 3½ miles long on the east bank of Whau Stream. Locally, as at Whau Creek near New Lynn, it has been carved into a stream terrace about 20 feet above sea level. It is underlain either by Tertiary strata or by silts and lignitic shales of Pleistocene age.

A minor feature of topographic interest is the existence of a relatively broad floodplain above a temporary baselevel afforded by a lava barrier just upstream from Western Springs in the valley of Motion's Creek, which enters Waitemata Harbour immediately east of Point Chevalier. Oakley Creek shows an exactly similar floodplain. Mention may finally be made of two circular shallow hollows about 2 chains across on the east bank of Whau Creek near its mouth; they appear to represent sinkholes comparable with those described by Henderson and Grange (1926) from near Ngaruawahia where the surface collapse that has occurred is the result of the removal of incoherent sands below the surface by groundwater streams.

COAST.

Recent submergence of North Auckland and Auckland regions is so well known that there is no need to detail the evidence of its occurrence. Turner and Bartrum (1929) show that it followed a sharp uplift of the same order of magnitude as itself at a date subsequent to the outbreak of early members of the cluster of basaltic volcanoes characterising the Auckland isthmus.

A bore sunk to a depth of 125 feet below mean high water level in Waitemata Harbour south of Northcote Peninsula failed to pass through the Recent silts that have filled an ancient channel excavated during the phase of uplift referred to.* This implies submergence of the order of not less than 150 feet.

At first sight the relatively straight coastline on the west of the area now described offers no evidence of submergence, but on close survey the evidence required is supplied by the drowned mouths of some of the larger streams, such as Piha Stream. Presuming that initially this shoreline was deeply embayed, its present extremely simple nature, which has almost reached maturity in the shoreline cycle, shows that there has been very considerable retrogression of the coastal cliffs since submergence was completed. Between North Head and Karekare these cliffs are now protected by a belt of sand 5 miles long and nearly three-quarters of a mile in maximum width (near Ohaka Head). Locally there were once lagoons behind barrier

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* Information supplied by Mr N. L. Vickerman, Assistant Engineer, Auckland Harbour Board.

beaches or spits, but these have now been filled by swamp or wind-blown material. This recent progradation is due to abundant supply of sand from both north and south of the area as a result of wave erosion of a coast formed of soft poorly consolidated sands, largely aëolian in origin, which build plateau-like ranges as much as 600 feet and more in height. From Karekare north there are precipitous sea-cliffs (see Pl. 12, Fig. 8) sometimes as much as 600 feet in height interspersed with sandy bays where the story of fairly recent progradation may again be read, as, for example, in a long, forested foredune at Piha and a small more recent one at White's Beach south of the mouth of Anawhata Stream.

Minor shoreline features include the usual stacks and reefs, while "tunnels" and caves are frequent both in ancient and modern sea-cliffs and usually have been excavated along fault or major joint fractures, though occasionally along dykes with transverse columnar jointing which have proved a ready prey to the waves. There is an excellent group of six of these "tunnels" and caves separated by a wide belt of sand from the sea near Windy Point, 2 miles north of Manukau North Head, which were regarded by Smith (1881) as indicative of recent uplift of the shore relative to sea level; there is no evidence, however, that their floors, now buried beneath sand, are above sea level.

Bartrum (1937) has described from the sea-cliffs at Mercer's Bay north of Karekare a vast natural shaft descending 300 feet to sea level from its mouth high up on the cliffs and with a width of from 75 feet to 90 feet. A tunnel 200 yards long was carved along a zone of close-spaced sheeted fractures until it intersected a transverse dyke 12 feet wide with prominent horizontal columns which have collapsed above the tunnel and thus caused the shaft.

At the base of most of the headands of the coast-line there are horizontal platforms eroded from the resistant conglomerates even where they are bedded in inclined sheets and normally from 2 feet to 4 feet above mean high water level; they descend steeply at their outer edges into water seldom less than from 15 feet to 20 feet in depth (see Pl. 11, Fig. 4). Landwards they commonly are overhung by the sea-cliffs, which are seen to be suffering excavation at their bases. Their surface is sometimes rough and irregular, but on wider platforms in any but the extremely coarse fragmental beds it normally is level and covered by shallow pools of water. Hutton (1870) regarded them as proof of recent shoreline emergence, but Bartrum (1923, 1926, 1935) has claimed that they are the product of storm waves of the sea at its present stance, while he has ascribed the frequent planation of their surfaces to subaërial processes which have reduced elevations to the levels of adjacent pools of water. Wentworth (1938) at Hawaii and Jutson (1940) from Port Philip Bay, Victoria, have described shore platforms of closely similar type; neither of these writers has made reference to the prior work of Bartrum. The latter's theory of origin appears to receive support from the fact that the only platform of this type in Manukau Harbour, apart from one at North Head, is eroded in volcanic conglomerate at Puponga Point where it meets waves driven through the harbour entrance by westerly gales.

STRATIGRAPHY.

Synopsis.

The oldest rocks actually exposed in the area are the Lower Miocene sediments of the Waitemata Series, but the existence of a buried older basement is afforded by pebbles in bands of conglomerate present in these sediments; this older basement is constituted by Mesozoic greywackes and Onerahi rocks (? Mid-Eocene).

The Waitemata strata are exposed only in the eastern lowlands and westwards pass under the volcanic rocks of the Manukau Breccia Series. Although the two series are conformable one with the other, occasional disconformities indicate some variation of conditions of deposition whilst the complete sequence was accumulating.

Near Avondale, New Lynn and Point Chevalier, Pleistocene clays, silts and occasional lignitic layers, rest unconformably on the Waitemata beds. They are shallow-water floodplain deposits accumulated in deep valleys excavated in the Tertiary terrain. They have been affected by later members of the compressional movements that have caused severe local folding and thrusting of the underlying Waitemata beds, for near New Lynn they are gently and occasionally even fairly steeply inclined. In addition, at Cornwallis, on the east coast of Puponga Point, Manukau Harbour, there are poorly consolidated dune sands of Pleistocene age rich in titaniferous magnetite and referable to the "Lignite Formation" of Hochstetter (1867) which is prominently developed in a high sand range which runs south-south-east for over 25 miles from Manukau South Head to the mouth of Waikato River (Gilbert, 1921).

Buried Mesozoic and Early Tertiary Basement.

Greywacke pebbles up to 1½ inches in diameter occur in a thin band of conglomerate of the Waitemata Series (Lower Miocene) at Blockhouse Bay, Manukau Harbour. Greywackes outcrop freely about 20 miles to the north-east and east in the islands of Hauraki Gulf and on the mainland at Maraetai (Firth, 1930); Ferrar (1934) has referred these rocks in the adjacent northern Rodney Subdivision to the Waipapa Series of probable Jurassic age.

Angular blocks of poorly foraminiferal argillaceous limestone ranging up to 3½ feet in diameter, though usually much smaller, and closely similar to the limestone of the Onerahi Series (see Ferrar, *loc. cit.*), which Finlay and Marwick (1940) have assigned to the Bortonian (Middle Eocene), occur in Waitemata sediments at various places on the Manukau north coast, as at Hillsborough Bay and a little east of Blockhouse Bay. These blocks clearly have not been transported far, for their material is very soft; they indicate, therefore, the existence near at hand in Waitemata times of a moderately elevated coast composed of this limestone, although it is not known to-day to outcrop nearer to Auckland than Dairy Flat and Okuru, about 15 miles north of Auckland City. These included fragments represent part of the evidence used by Park (1886), Bartrum (1924) and Bartrum and Turner (1929) in support of erosional unconformity between the Waitemata sediments and those of the preceding Onerahi Series. The extent of erosion must have been considerable, for ammonite-bearing concretions derived from the Danian Otamatea Series (Ferrar, 1934), which underlies the Onerahi Series, occur in Waitematan conglomerates (Albany conglomerates of Bartrum, *loc.*

cit.) at Hawke's Quarry near Kaukapakapa, 20 miles north-west of Auckland.*

Waitemata Series—Hutchinsonian (Lower Miocene).

As near Auckland, the typical rocks are friable yellowish-brown feldspathic sandstones interbedded with light-grey to bluish thinner mudstones often well laminated in character. They contain few determinable fossils other than Foraminifera. There are, however, variants from this general type of sediment; for example, at Waikowhai and Blockhouse Bays on the Manukau Harbour there is a 12-feet band of intraformational conglomerate with boulders as much as 1 foot and more in diameter and composed of sandstone indistinguishable from that of adjacent Waitemata beds. Then on the western side of Puponga Point boulder-like masses as much as 1 foot across of white marly mudstone encased in a thin skin of volcanic tuff occur in false-bedded sediments which here include lenses of coarse tuff. These "boulders" evidently are mud balls rolled by currents in shallow water. About half a mile west of this occurrence there is distinct discontinuity of bedding indicated by the superposition of a gently inclined series of argillaceous beds upon a steep, undulating surface of gritty strata. Shallow-water conditions of deposition are demonstrated again by pebble bands in various places such as Blockhouse Bay, Shag Point and Titirangi Bay, while at the eastern head of Onehunga Beach on the same northern coast of Manukau Harbour as the last localities there is a thin bed (noted by Park, 1886) which contains rounded pebbles of pumice up to ½ an inch in diameter, as well as worm tubes and carbonaceous matter. Evidence of fairly general shallow-water deposition is thus common, yet Mr. W. J. Parr, of Melbourne, considers that the Foraminifera of some of the finer-grained beds suggest deeper waters than obtained for any others of the numerous foraminiferal horizons near Auckland that he has examined.†

Some of the pebble bands mentioned deserve further consideration. At Blockhouse Bay, about 200 yards east of Duck Creek, a 5 foot bed outcrops, dipping at 50° to the north-north-west; it has pebbles as much as 2¼ inches in diameter at its base, but becomes progressively finer upwards until it grades into foraminiferal sandstone. In it are greywacke of the Waipapa Series (Ferrar, 1925), amygdaloidal basalt and biotite dacite or rhyolite; this last probably is the same rock as the rhyolite that Bartrum (1924) records as fragments in Waitemata beds at Riverhead 14 miles north of Blockhouse Bay. No similar rock is known *in situ* within at least 20 miles of Auckland.

At Shag Point, about 300 yards south-west of Titirangi Beach, several pebble bands from 1 foot to 4 feet in depth alternate with sandstone in a series dipping at 40° to the east-north-east. Mulgan (1902) noted one of the bands and regarded it as a phase of the Parnell grit which is described below. The presence of gneissic diorite and epidiorite amongst the pebbles, however, indicates that correlation is with the Albany conglomerates (Bartrum, 1920, 1924), in which gneissic diorites are most characteristic included rocks. Typical Parnell grit is indeed present, for the pebble series has been overthrust upon it along a plane that dips at 30° to the north-west.

* Oral communication from Professor J. A. Bartrum.

† Personal communication.

The Parnell grit has been described so often by various writers and its origin so freely discussed (see, for example, Turner and Bartrum, 1929) that no good purpose can be served by considering it in detail in this paper, particularly as no fresh facts have come to light. The main occurrences are a 10 foot bed dipping to the south-east half a mile west of White Bluff and two yellowish bands 13 feet thick separated by 25 feet of normal Waitemata sandstone between Waikowhai and Mission Bays, half a mile west of the previously-mentioned outcrop. There are also five exposures of the same type of rock on the shore between Titirangi and Little Muddy Creek and just west of Shag Point there is a further outcrop in which a 3 foot bed with large blocks of white foraminiferal marl separates basal coarse grit from an upper stratum of coarser nature. In addition Mr. C. W. Firth has informed the writer that no fewer than four beds of this characteristic rock were encountered in a drainage tunnel 1½ miles long between New Lynn and Karaka Bay, south of there on the Manukau coast.

In typical Parnell Grit there are variably sized fragments of volcanic rocks (mainly andesites) and of black shale and sandstone and, as a rule, numerous broken polyzoans. These last are particularly abundant in the beds at Mission Bay and include both slender and massive cup-shaped forms, these latter often over 2 inches in diameter; in addition there are fragments of *Pecten* and other molluscs and of corals, echinoids, worm tubes and brachiopods. Such fossils as these, which rarely are specifically identifiable, are usually the only larger forms present in the Waitemata beds throughout the whole of their extent and the only satisfactory macrofauna yet derived from them near Auckland is that at Waiheke Island, which Powell and Bartrum (1929) have referred to the Hutchinsonian (Lower Miocene). Foraminiferal faunas are, however, obtainable from a number of localities; samples from 13 of these were submitted to Mr. W. J. Parr, of Melbourne, who kindly made determinations of species. Dr. H. J. Finlay's recent intensive work on New Zealand Foraminifera, however, has made revision of the determinations necessary, and the writer is greatly indebted to Dr. Finlay for undertaking this onerous task and furnishing the check list of nearly 160 species that is published as an appendix to this paper.

The Manukau Breccia Series.

General Description. Beds of this volcanic series have been noted and discussed, particularly as regards their relation to the Waitemata Series, by Hochstetter (1864), Hutton (1870), Cox (1881, 1882) and Park (1886, 1889). Cox and similarly Park in his later report (1889) believed that they are an upper conformable continuation of the Waitemata Series due to culmination of the same series of volcanic eruptions as gave rise to the Parnell Grit. Bartrum (1924) found no indication of unconformity between the breccias and the Waitemata sediments near Kaukapakapa, north of the present area, but later Turner and he (1929) noted that in a water-supply tunnel at Huia, on the Manukau Harbour, the volcanic beds rest on an uneven surface eroded from Waitemata sediments. The conclusions reached during the present study are given in a later section of this paper.

The rocks of the Waitakere Range, which commonly are referred to as the Manukau Breccia Series, are andesitic fragmental beds with numerous intrusive dykes and minor interbedded flows. They cover nearly 90 square miles in the area now described and continue to the southern arms of Kaipara Harbour, about 35 miles north-west of Auckland. Rock masses similar in petrographic and other characters are extensively developed in Coromandel Peninsula and its northern extension in Great and Little Barrier Islands and in the northern portions of Auckland Province, as at Whangarei (Ferrar, 1925), Hokianga Heads, Whangaroa and North Cape (McKay, 1894).

In grade the various beds of this series vary in the Waitakere Ranges from fine grained, well-bedded tuffs to coarse breccias with blocks as much as 5 feet across (see Pl. 11, Fig. 1; Pl. 12, Fig. 8). The constituent fragments usually are angular, but nevertheless there frequently are beds of well-rounded boulders and finer material which usually show good assorting and large-scale false bedding. These latter characters, with common sub-horizontal bedding, suggest that they are beach deposits; further evidence in favour of marine deposition of the series will be given later. Petrographically there is remarkable uniformity of rock-type; andesites alone are represented and pyroxene varieties of these rocks preponderate. The beds are considerably broken by joints and other fracture planes which have a general east-west direction in the southern portion of the coast, but movement has seldom taken place along these fractures for the dissevered portions of boulders on opposite sides of them are rarely displaced. The joint crevices often are filled by calcite; opal occurs as the filling at Whatipu and Puponga with the addition of zeolites at this last locality. Faults are not entirely absent and at Paratutai, Manukau North Head, an example occurs where they are referable to two periods, for two small dykes have been cut by the same normal fault, which has displaced the upper dyke little more than 3 feet, although the lower and evidently the earlier dyke has been moved 10 feet.

Because of the highly competent nature of the beds, folds occur very rarely in the breccia series, although local belts of acute folding and thrusting are common in the weaker underlying Waitemata sediments in most regions of their occurrence (see Pl. 11, Fig. 2). In ancient sea cliffs about a mile north of Pararaha Stream, on the Tasman coast, however, fine-grained bedded tuffs with occasional lenses of conglomerate have been crumpled into what is largely a confused jumble of relatively small blocks of strata (see Pl. 11, Fig. 3). In the centre there is a series of almost vertical S-shaped folds separated by a fault from a triangular mass which appears to represent a large S-shaped fold of which the crest has been outsqueezed with the production of minor drag folds. As the section is followed north, close-spaced variously-inclined thrust planes dipping to the north-west succeed the folds and in their direction parallel the chief structural direction noted by Turner and Bartrum (1929) in Waitemata beds near Auckland.

The finer-grained tuffs usually constitute relatively thin, finely laminated strata interbedded with beds of coarse débris which predominate amongst the fragmental beds of the present district in

contrast with the relation that obtains in the northern half of the Waitakere mass, where massive tuffaceous sandstones are more abundant than coarse clastics. A particularly good exposure of these fine-grained tuffs occurs on the West Coast Road not far east of its junction with Piha Road. They contain material petrographically identical with that of the coarser clastics and include Foraminifera near Nihotupu Dam and on the West Coast Road 1 mile east of Waiatarua, though by no means so freely as the massive tuffaceous sandstones of the northern half of Waitakere Range beyond the present area. Dr. H. J. Finlay reports that tuffs collected by the present writer from the Scenic Drive about 1 mile north of Titirangi contain indeterminate Globigerinidae with siliceous forms which apparently have come from Cretaceous strata disrupted by the volcanic eruptions.

Bedding discontinuities often appear in the tuffs and at Henderson Valley there is a decided unconformity comparable with one figured by Laws (1931) from the Tertiary sediments near Papakura, for upper beds of fine tuff dipping gently to the south-west, rest on the truncated inclined edges of lower beds which dip more steeply to the north-west.

Clastic Dykes. A number of interesting clastic dykes intersect the breccias at various points on the Tasman coastal section, though concentrated mainly about three-quarters of a mile north of Manukau North Head. They appear to occur only in ancient or modern sea-cliffs and have not been observed in the many excellent sections afforded by stream gorges further inland The light colour of many of them contrasts with the sombre tone of the breccias and they were duly noted by Hutton (1870). More recently Taylor (1930) has made a detailed study of seven of them and has stated that they are ". . . clastic dykes the material of which has been forced up from below during a state of tension in the over-lying breccia." As Taylor's view of their origin is not accepted by the writer it will be necessary to describe individual dykes in some detail.

The most prominent of the dykes (A of Taylor) appears in abandoned sea cliffs about three-quarters of a mile north of the Heads as a steep, Y-shaped, light-coloured mass 8 feet wide at the fork of the Y 60 feet above the base of the cliff, but only three feet in width at the base (see Pl. 12, Fig. 5). The northern fork of the Y continues upwards for a further 40 feet or more to the top of the cliff, but the other soon pinches out. The filling is soft, fine-textured whitish tuff with numerous fragments of acidic pumice which usually are small, but occasionally may be as much as 2 inches in diameter. Dyke B of Taylor is a few yards further north, and is an irregular sheet, 18 feet in width below, which rises vertically for 70 feet. It is filled for 30 feet from ground level by material indistinguishable from that of the breccia of its walls and includes blocks of andesite as much as 18 inches across. There is then a horizontal joint plane and the filling thereafter becomes progressively finer in grain. The basal 10 feet of this finer material is andesitic and shows faint but distinct bedding, the lower layers being sub-horizontal and gently convex viewed from above, but the higher steeply inclined as if an open fissure had been filled by material rilling from above perhaps with

the assistance of rain waters. Above this purely andesitic material. much of the white pumiceous filling noted in Dyke A enters as a constituent. At a point 40 feet above the base of the cliff, the dyke divides into two branches which pass around a narrow horse of breccia 30 feet in length and then reunite, while the dyke flattens to dip at 30° to the south-south-west as it passes to the top of the cliff. A few yards further north the next dyke (C of Taylor), which is only a few inches in width, contains fine-textured white fragmental material in its lower portions, but as it gains height the size of fragment becomes larger and the white constituents become eliminated from the general andesitic filling.

Dyke D of Taylor is 3 feet wide where it rises steeply from floor level at the south-west corner of the "Big Cave," a familiar landmark of the district, but narrows rapidly to 6 inches within the height of 3 feet; it then as rapidly expands to 30 inches and maintains this width to where it outcrops 30 feet up on the top of a small promontory. Similar irregularities of width characterise it along its strike in the cave. The walls of the fissure that it occupies show vertical slickensides and 2 feet vertical displacement of one wall with respect to the other is demonstrated by the displaced halves of a dissevered boulder. Both in this and the next dyke (E), which rises ill-defined from the roof of the Big Cave, the filling includes white pumiceous fragments in the lower portions, although higher it is indistinguishable from adjacent breccia. Another dyke 2 chains south of A has not been described by Taylor (*loc. cit.*); it is a regular sheet 6 inches in thickness which extends 30 feet to the top of a low cliff. It differs from previous dykes described in that the lowest 8 feet of its filling is of andesitic fragments although higher up white pumiceous material dominates.

In the low cliffs at the northern head of the sand bight at Whatipu there is a further infilled fissure 10 feet in width which was noted by Taylor; its filling is fairly fine andesitic tuff without any of the white material. A few of these clastic dykes also occur in sea cliffs north of the present area, while at Windy Point, about half a mile north of the main group of dykes, there is an example which differs markedly from all others in its characters, though regarded by Taylor as analogous to the others (see Pl. 12, Fig. 7). It is a wedge-shaped sheet which is 5 feet in thickness at its upper limit, where it dips east-south-east at 20°, but decreases in width downwards with accompanying flattening of dip until it pinches out at the base of the cliffs. Northwards it makes contact with a mass of highly angular material which Taylor, following Hutton (1870), regarded as denoting a fault zone. This is not so, for the material is agglomerate which marks the site of an early eruptive vent and includes coarse fragments of glassy slaggy lava, others of oxidised greatly vesiculated rock and angular blocks of poorly vesicular andesite identical with that in the breccias near at hand and sometimes as much as 30 inches by 10 inches in exposed dimensions. In addition there are fragments of brown andesitic pumice and of highly pyritised andesites, while tuff occurs both as scanty matrix and as large blocks. Perfectly shaped crystals of augite reaching ½ an inch in length abound in the tuff, while a thin-section shows in addition green-

ish hornblende and hypersthene. Probably the most instructive constituents of this agglomerate, however, are spirally twisted fusiform lava bombs; one that was measured was 1 foot in length and weighed 22lbs. The filling of the adjacent dyke is identical in character with the material of the agglomerate, except that it is not so coarse, and contrasts with that of all other dykes. It clearly represents superficial ejecta which have gravitated into an open fissure produced by magmatic heaving, and it is unfortunate that Taylor (*loc. cit.*) should have regarded this particular dyke as similar to the others.

As already mentioned, Taylor believed that the dykes are tension fissures filled from below by injection. The source of the filling in his view was crystal tuff which underlay the breccias that are the country rock of the dykes and was exposed just north of Windy Point, where upthrown by the fault that he and Hutton (1870) postulated at this place. Tuffs certainly occur locally, but do not contain the white material characteristic of the dykes which was believed by Taylor to be andesite selectively kaolinised because of its pumiceous nature. Microscope study shows that this is not so and that the material is acidic (see Pl. 12, Fig. 6).

The writer considers that Taylor's hypothesis of origin of these dykes is unsatisfactory for several reasons:—

1. Apart from their occurrence in the dykes, the white pumiceous constituents of the filling are absent from the great mass of fragmental rocks that constitutes Waitakere Range.
2. The mode of filling of dyke B seems incompatible with injection from below on account of bedding layers which suggest strongly that the material rilled in from above.
3. Unless its fragments were "rafted" by muds of which no trace now exists, it is difficult to understand how the very coarse filling at the base of dyke B can have been emplaced by injection from below.
4. In most of the dykes the pumiceous filling is in the basal portions and is replaced at higher levels by andesitic material. In one instance this relation is reversed. This fact is more readily explained by a theory that invokes filling from above than by Taylor's hypothesis.
5. The dyke at Windy Point has been shown almost unquestionably to represent a fissure filled from above.

The writer believes that fissures developed probably as a consequence of broad compressional arching and that these were filled by material washed in by rain waters and fallen from the upper weathering edges of the fissures. Dyke B is strong evidence in support of this belief, while that at Windy Point has an analogous origin. Open fissures appear occasionally on the tops of some of the sea cliffs of the area where erosion has freed the rock from its cover of soil. Under the writer's hypothesis the explanation of the pumiceous filling of the dykes presents no difficulty. Taylor (1927) records a deposit of similar pumice near Te Henga, 10 miles north of the main group of dykes, and Professor Bartrum has informed the writer that, a mile south of Te Henga, a subaërial deposit that includes rhyolitic pumice outcrops at high levels above the sea cliffs and that pumice also enters into the constitution of the elevated range

of Pleistocene sands between Manukau North Head and Port Waikato. It is evident, therefore, that pumice was freely distributed in the area during the Pleistocene; it could readily have been washed into any open fissures by rain waters.

Huge Blocks of Tuff in Breccias at Whatipu. Hutton (1870) remarked on colossal blocks of fine-grained sediment (which he believed to represent sandstone of the Waitemata Series) in the normal breccias at Manukau North Head. One such block measures 40 feet by 30 feet by 20 feet, while another larger one nearby is over 2 chains across its bedding and has even greater length. They lie in various attitudes and are not of Waitemata sandstone but of andesitic tuff identical with that of similar beds of the breccia series. The great number of dykes in the cliffs of the locality suggests that the site of the vent that upheaved these blocks lay close at hand.

Dykes and Sills. Several of the earlier writers on the area noted the numerous dykes in the Manukau breccias at Paratutai, the knob-like island at North Head, and two parallel sheet-like masses were regarded by Hutton (1870) as interbedded flows; they have glassy selvedges on both upper and lower surfaces and are clearly transgressive on the opposite side of the island from that where they accord with the bedding. They are thus dykes continued as sills.

Occasional thin sills were noted by the writer, but the vast majority of the very numerous intrusions are dykes; most of them are less than 6 feet across and very few exceed 20 feet. They may occur wherever there are coarse fragmental beds, but have a distinct tendency to cluster in groups as if close to eruptive centres. In spite of the coarseness of the breccias which they invade, dykes less than 1 inch in width may be followed for several yards, and one or two less than 3 feet thick were traced for nearly a quarter of a mile.

The dyke rocks are bluish-black pyroxene andesites which vary little in mineralogical constitution but range in texture from fine-grained aphyric types to others with phenocrysts of feldspar or pyroxene as much as ½ an inch in length. Two dykes which are only 12 feet apart in the south branch of Piha Stream, three-quarters of a mile above its confluence, illustrate these extremes of texture; they probably represent injections that differ in date, but other explanations are possible.

Some of the dyke rocks are moderately, though not highly, vesicular and do not appear to have occluded any noteworthy quantities of volatile constituents, for wall rocks are unaltered in all cases. The vesicles of a dyke ½ a mile north of Lion Rock, Piha, have a lining of oxide or hydroxide of manganese. In other cases there may be a pellicle of a bright-blue material which was early noted by Hochstetter (1864). It is also common in the vesicles of lavas, but is in so thin a film that its composition could not be determined, although it was found to contain iron.

Flows. Earlier writers have not recorded the occurrence of flows, although Bartrum (1930) evidently was aware of their existence. They are not as conspicuous as the dykes, but are by no means infrequent, particularly at Karekare and Piha and along West Coast Road; most of them appear to be relatively thin and inextensive. A narrow deep flow associated with an interesting breccia beneath

it outcrops in a promontory called "The Watchman," which terminates in lofty bluffs on the north side of Karekare Stream. It is limited on either side by what is taken to be a friction breccia, for it is composed wholly of fragments identical in character with the rock of the flow, which is a characteristic vitrophyric type with flow banding made prominent by parallel lenticular streaks of whitish glass. The breccia beneath the flow is unlike the usual breccias, for it lacks bedding and consists of angular fragments of the characteristic overlying lava set in a matrix of red oxidised ash. It is believed to be an agglomerate deposited very close to an earlier centre of eruption.

One of the best exposures of flows is a series of six, some as much as 50 feet in depth, in sea cliffs 500 feet in height 1½ miles north of Piha Stream.

Although Bartrum (1930) has described pillow lavas from Muriwai and informs the writer that another thick mass occurs near Te Henga north of the present area, none of the western flows observed by the writer were of this type. He noted them only at the head of the lake impounded by Nihotupu Dam in a mass about 50 feet in depth. Only the upper part of the exposure shows pillows and the rock below this appears to have columnar jointing. Three fan-like columnar structures are exposed in a quarry near at hand and it is possible that they, in common with the columnar lava beneath the pillows, have been formed by fairly slow upwelling of lava to form dome-like masses in the manner postulated by Bartrum (*loc. cit.*) for comparable structures at Muriwai. The interstices between pillows of the Nihotupu flow are occupied by tuff, while large vesicles in the lava contain opal or calcite, or, more rarely, chabazite or aragonite. Foraminiferal tuff lies beneath the lava, so that this latter probably represents a submarine flow. Other flows of the area possibly also were submarine but escaped too rapidly to permit the formation of pillows.

Origin and Mode of Accumulation of Manukau Breccias. Park (1889) stated that the fragmental volcanic rocks of Waitakere Range were the product of submarine eruptions in shallow seas; Bartrum (1929) came to the same conclusion and believed that most of the parent volcanoes were located not far west of the present coast.

One of the most puzzling features of the rocks concerned is that they do not include in more than very minor amount the highly scoriaceous material that is so characteristic of normal volcanoes; their constituent blocks appear to be fragments disrupted either by explosions or by a vigorous eroding agent, such as waves, from earlier poorly vesicular lava. Limitations of space do not permit discussion of this major problem.

The writer believes that transport and deposition were effected by the sea, for the rocks are usually in sub-horizontal well-bedded sheets which lack the foreset bedding that is characteristic of stream fans or deltas, although at times bedding layers of any kind are absent from coarse breccias and fine tuffs alike. Confirmation of this belief is given by the fact that marine fossils have been found in the series in a number of widely separated localities and include Foraminifera at Nihotupu, Waiatarua and near Titirangi, as well as a few species of molluscs in moderately fine breccia at Henderson Valley.

The blocks of the breccias are often so angular that they cannot have been transported far; the areas of provenance, therefore, must have been fairly near at hand. Support is given to this conclusion by the discovery in a number of localities of agglomerates which, in some cases, are clearly occupying the actual vents of extinct volcanoes. One such example already has been described from Windy Point, between Manukau North Head and Karekare; another is afforded by a funnel-shaped mass of agglomerate 80 yards in width which penetrates well-bedded breccia-conglomerate associated with a number of dykes immediately south of the Blow Hole, Piha. In its material there are red oxidised blocks of scoriaceous lava as much as 4 feet in diameter. A similar pipe outcrops at White's Bay, 2 miles north of Piha Stream; it is 33 feet wide at beach level but enlarges upwards as it passes through well-bedded conglomerate which dips at 40° to the south-west. It is bordered on the north by highly irregular intrusions and has given rise at a height of 100 feet above the beach to a columnar sub-horizontal lava flow. Additional evidence of the proximity of an important eruptive vent continues for some distance north in this bay, for discontinuous beds composed of scoriaceous fragments and lenses of red oxidised ash are common along with many irregular small flows of lava.

Reasons already have been given for the belief that other centres of eruption were located close to Manukau North Head and to the Watchman at Karekare.

Park (1886) believed that the topography at Puponga Point, Manukau Harbour, was a reflection of an ancient crater located there; the rocks of the locality are wholly coarse conglomerates interbedded with thick beds of tuff and the topography to which Park drew attention is merely a cuesta developed on a bed of conglomerate folded into an anticline or dome that has been faulted on its southern flank.

Age of Manukau Breccias and their Relation to the Waitemata Series.

Hochstetter (1864), Cox (1881) and Park (1889) have agreed that the Waitemata beds and the volcanic strata above them form a conformable succession, although Park had denied this in earlier writings. Bartrum (1924) reached the same conclusion with regard to the two series of beds in the Kaukapakapa region, although later Turner and he (1929) noted that in a water supply tunnel at Huia, on the north coast of Manukau Harbour, the volcanic series appeared to rest on a surface eroded upon Waitemata sediments. Professor Bartrum informs the writer, however, that this appearance of unconformity may be the result of the slipping of the massive breccias down the slope of the spur that is traversed by the tunnel.

The writer's study of various contacts has convinced him that conformity is the rule. As already described in an early section, the upper beds of the Waitemata Series near Puponga Point have bedding discontinuities and include rolled mud balls which are also the product of shallow water deposition. These upper beds are mainly tuffaceous sandstones with lenses of coarse tuff and are followed with complete conformity by typical coarse volcanic conglomerate.

Along the greater part of the eastern slopes of the Waitakere Hills there is no marked change in type of sediment as one passes from Waitemata beds to those of the Manukau breccias, for the lowest strata of this latter series are fine-grained and weather to whitish or mottled clays which obscure the actual contacts. In Opanuku Stream, Henderson Valley, however, fine-grained horizontally bedded sandstones of Waitemata type show gradual passage into fine volcanic breccias which undoubtedly are members of the volcanic series. From these latter Mr. A. W. B. Powell obtained *Lima colorata* (Hutton) and *Opella* cf. *subfimbriata* (Suter) which enabled him to correlate the containing strata with the Hutchinsonian (Lower Miocene) fossiliferous beds at Pakaurangi Point, Kaipara Harbour. A little south of Motutara, north of the area now described, there is a small molluscan faunule in sandstones of the Manukau Breccia Series; it has been described by Powell (1935) and referred to the Awamoan (Middle Miocene). The Manukau breccias of Motutara thus are younger than the Hutchinsonian (Lower Miocene) beds of the Waitemata Series at Oneroa, Waiheke Is. (Powell and Bartrum, 1929).

PLEISTOCENE AND RECENT FORMATIONS.

Subaërial Pleistocene Sands. Near Cornwallis on the south-east side of Puponga Point, Manukau Harbour, there is a bed exposed for a height of 10 feet of soft partially consolidated sands rich in oxidised titaniferous magnetite. As shown by his section, Hochstetter (1864, pp. 17, 18; 1867) placed these sands in the same series as Waitemata beds exposed beneath them; they differ in character, however, from any known Waitemata strata, and in addition exemplify the large scale false bedding that is characteristic of dune sands. Their exact counterparts appear in the sands of the Pleistocene range between Manukau South Head and Waikato River (Gilbert, 1921). Hochstetter (*loc. cit.*) placed these latter in his Pleistocene "Lignite Formation"; Ferrar (1934) more recently has referred them to his Kaihu Sands (Pleistocene). They attain an elevation of over 600 feet in higher parts of the plateau-like range mentioned above and have wide distribution north of the present area beginning at Anawhata, 9 miles north of Manukau North Head, where they occur above the sea cliffs in remnants of a dissected plateau, roughly 500 feet in average height, which broadens rapidly beyond Te Henga to form a conspicuous feature of the landscape.

The occurrence of these wind-bedded sands at Puponga Point is of interest in demonstrating that when they were deposited the entrance to Manukau Harbour was not in its present location but further south.

Pleistocene Clays, Silts and Lignites. Cox (1884) early examined clays with seams of impure lignite near Whau Creek, Waitemata Harbour, and correlated them with Hochstetter's Lignite Formation of the Manukau lowlands. Turner and Bartrum (1929) have dealt with them more recently and note that the 40 feet to 60 feet erosion level that is so prominent around the shores of Waitemata Harbour is underlain in part by these beds as well as by Waitemata strata and occasional tuffs that resulted from early eruptions of the basaltic volcanoes of the Auckland isthmus.

Beds of this Pleistocene formation cover about 4 square miles of the present area, with their greatest development near Avondale and there is good reason to believe that they once continued thence to Hobsonville, 7 miles north, as a broad sheet which has subsequently been removed by erosion.

In the main they consist of white or grey plastic clays with not infrequent pumice and other sands and silts and many thin lensoid beds of lignitic mudstone which are especially freely developed at Point Chevalier Beach. Gardner's clay pit, near New Lynn Railway Station, affords an excellent section of the formation; in several of the beds there are woody stems in the position of growth with roots attached. Pumice pebbles as much as 3 inches in diameter occur in some of the layers, and at Hobsonville there are thin beds of small pebbles of greywacke and other rocks (Turner and Bartrum, 1929).

The contact of this Pleistocene clay formation with underlying Tertiary strata is seldom visible, but Mr. C. W. Firth states that excavations for a sewage tunnel between New Lynn and Karaka Bay, south on the Manukau coast, showed clearly that the younger beds occupy steep-walled trenches eroded from Waitemata strata.* Similar relations are suggested near Point Chevalier, while the fact that at Whau Creek, near Avondale, excavations for the foundations of a bridge reached 50 feet below sea level without passing below the Pleistocene clays shows that the trenches occupied by these latter were carved deep below modern sea level; this trenching indicates that sharp uplift (or lowering of sea level) preceded the deposition of the beds concerned. The observations just recorded also give information as to the depth of this Pleistocene series, for, while descending to more than 50 feet below sea level at Whau Bridge, its beds are found at 100 feet above that level south of New Lynn. Although generally bedded horizontally, as noted by Turner and Bartrum (*loc. cit.*) they may locally be gently inclined; south of New Lynn their dip in one clay pit is 30°, so that they shared in the later of the compressional movements that have affected the underlying Waitemata sediments.

The writer agrees with the conclusion of Turner and Bartrum (*loc. cit.*) that this series of Pleistocene beds was deposited ". . . in lakes or on the swampy floors of the valleys of sluggish streams during progress of very slow subsidence."

Recent depoits of the present area include marine sands and muds which occupy drowned valleys in the submerged regions of Waitemata and Manukau harbours; extensive mudflats dotted here and there by groves of mangroves are ubiquitous around the shores and extend as tongues up most of the numerous tidal creeks. In addition, there are occasional floodplain deposits and, as already recorded, on the Tasman coast there has been recent progradation of the shore line by sand beaches followed by a relatively narrow belt of windblown sand which extends to the base of the former sea cliffs. It is only at Muriwai, well north of the present area, where the resistant rocks of the Manukau Breccia Series turn obliquely inland, that the

* Personal communication.

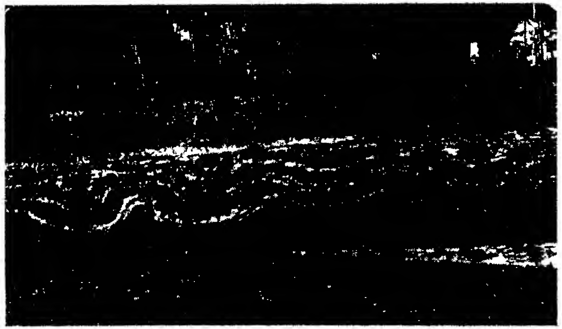


Fig. 1.—Intraformational drag folding due to delta slumping; tuffs of Manukau Breccias, 1 mile east of Big Muddy Creek, Manukau Harbour.

Fig. 2.—Deformation of Waitemata Series: shore at east end of Blockhouse Bay, Manukau Harbour.

Fig. 3.—Fault along crest of anticline; tuffs of Manukau Breccias near Pararaha Stream, Tasman Coast.

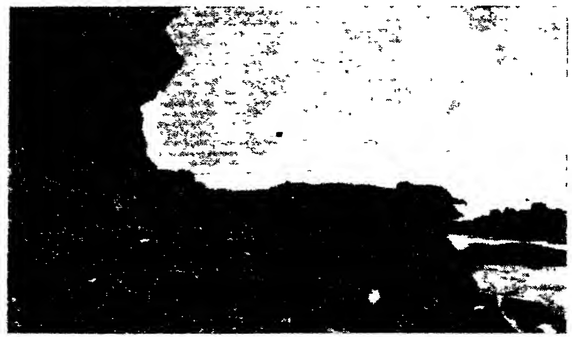


Fig. 4.—Short platform about 4 feet above high water level and about 40 feet in width; Manukau Breccias, Manukau North Head.

Facing page 64.]

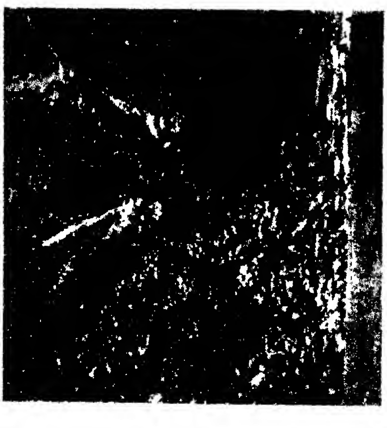


Fig. 5.—Clastic dykes A (Y-shaped) and B of Taylor (1930) in Manukau Breccias, three-quarters of a mile north of Manukau North Head.

Fig. 6.—Material of pumice in clastic dykes of Fig. 5; the phenocryst is hypersthene.

Fig. 7.—Clastic dyke filled by volcanic ejecta, Windy Point, two miles north of Manukau North Head. Note the bedding of adjacent breccias.

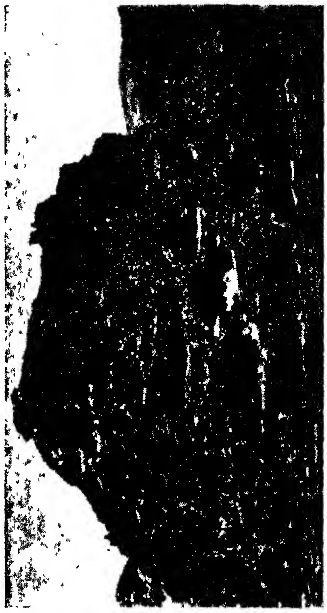
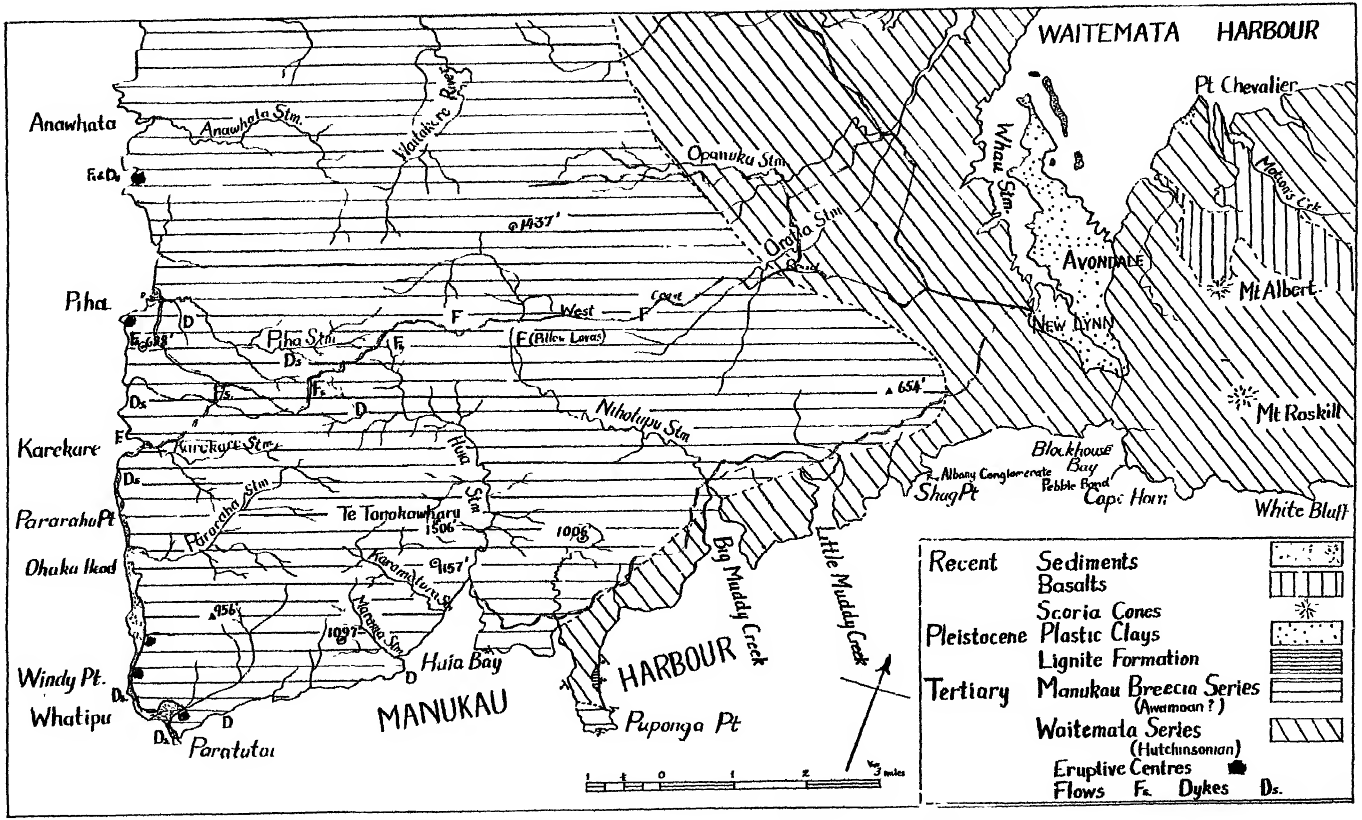


Fig. 8.—Differential weathering in 200 feet bluff of Manukau Breccias near Pararaha Stream, Tasman Coast.



Geological Sketch Map of Southern Waitakere Area.

belt of modern wind-blown sands materially increases its width and threatens danger to adjacent farm lands.

GEOLOGICAL HISTORY OF THE AREA.

The most interesting phases of the geological history of the area are those that concern late Tertiary and post-Tertiary time. These have been adequately dealt with by Turner and Bartrum (*loc. cit.*) and make so long a story that recapitulation of it is impracticable in this short paper. In any case no facts that materially affect the conclusions of these writers have been brought to light during the present study.

PETROGRAPHY OF THE MANUKAU BRECCIAS.

Nearly 120 thin-sections of rocks of the area were examined and included many made by the writer and others lent by Professor J. A. Bartrum. They indicate that there is little petrographical variation in the rocks of the volcanic series, as was indeed to be expected, for, although they had not undertaken systematic microscopic investigation, both Marshall (1925) and Bartrum (1925) have recorded that the rocks concerned essentially are andesites.

The typical rock, whether in dyke, flow or fragmental masses, is an hyalopilitic pyroxene andesite with augite and hypersthene in subequal proportions and commonly, though not always, as phenocrysts as well as in the groundmass. Plagioclase near andesine-labradorite in composition is the most persistent and abundant phenocryst; its crystals generally show zonal growth and both Albite and Carlsbad twins. Frequently they are pitted by zonally-arranged inclusions of glass and, in a few rare instances (e.g., S.62), include tiny needles of rutile. The groundmass typically consists of laths of feldspar with pyroxene and a good deal of glass; magnetite and ilmenite in small needles and dendritic growths are unusually prominent in the rocks of dykes near Whatipu, Manukau North Head (S.8; S.16) and cluster about vesicles filled with chlorite. This latter secondary mineral is derived from the pyroxenes and shows all stages in its replacement of those minerals: it has been dispersed freely throughout the fabric of the rocks.

In the rocks of widespread localities there are what appear to be chloritic replacements of original olivine, for they have the characteristic fractures, form and, more rarely, resorption borders, while a few unreplaced cores of olivine appear in the rock (S.23) of a 30-feet dyke in a former stack a quarter of a mile south of Ohaka Head. A green pleochroic mineral taken to be bowlingite is enclosed by chlorite in the rock of a large dyke (S. 34) 100 yards north of White's Bay; it has eminent cleavage, moderately high refractive index and birefringence about that of talc and is uniaxial.

Hornblende is rare, although it was found in andesitic fragments present in some of the clastic dykes, including that at Windy Point, and as small, rare crystals in other rocks, such as that of a dyke at Fishing Rock, Karekare. The two pyroxenes present in the rocks occasionally show a mutual reaction that has been noted by Bartrum (1917) from hypersthene-olivine basalt at Ruatangata, near Whangarei, and from a quartz norite at the Cleddau-Hollyford Saddle, Fiordland (Bartrum, 1920). The result of this reaction is

that earlier-formed hypersthene is rimmed by augite; Bowen (1928, pp. 58–59) has shown that reaction rims of this kind can only occur when there has been rapid cooling of the magma.

Marshall (1908) recorded a rhyolite intrusion at Karekare. The writer made an intensive unsuccessful search for this rock, and can only conclude that a superficially light-coloured weathered andesite has been mistaken macroscopically for rhyolite.

Chemical analyses of the rocks under description are not available, but Professor Bartrum has kindly allowed the publication of the following analysis of a pillow lava present in this same Manukau Breccia Series at Muriwai, 7 miles north of the area dealt with in this paper. The rock is similar microscopically to the more basic of the andesites described above. Analysis and calculation of the norm and classification under the C.I.P.W. system are the work of Mr. F. T. Seelye, of the Dominion Laboratory, Wellington.

Analysis of Composite Sample from Main Flow at Muriwai.

	Analysis	Mol Prop.	Norm.	
SiO_2	53.16	.886		
Al_2O_3	16.69	.164	Q.	8.6
Fe_2O_3	3.38	.021	or	6.12
FeO	4.88	.068	ab	27.25
MgO	3.51	.088	an	28.08
CaO	8.32	.148	di	8.99
Na_2O	3.17	.052	hy	8.94
K_2O	1.02	.011	mt	4.87
H_2O+	1.58		il	2.28
H_2O-	2.79		ap	0.67
CO_2	0.02			
TiO_2	1.15	.015		
ZrO_2	none			
P_2O_5	0.26			
S	0.02			
Cr_2O_3	none			
NiO	trace			
MnO	0.14			
SrO	? trace			
BaO	0.03			
	100.12			

Symbol: II. (4) 5. (3) 4. 4." Andose.

ACKNOWLEDGEMENTS.

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Appendix.

List of Foraminifera from the Waitemata Series, Manukau North Coast, determined by Dr. H. J. Finlay.

Localities.

1. Eastern promontory of Mission Bay.
2. West face of Cape Horn. 3-foot bed in centre of anticline (interpolated from Parr's list).
3. 1½ to 2-inch bed in lower part of same anticline.
4. An upper bed of same anticline, near small stream.
5. 25 yards west of first small stream from east end of Hillsborough Bay.
6. The same; softer sandstones west of small stream.
7. East side of same stream, Hillsborough Bay.
8. Below Parnell Grit, Blockhouse Bay.
9. 10 chains east of Duck Creek.
10. At base of point, western side of White's Bluff.
11. Five chains west of point, White's Bluff.
12. About 15 chains west of Locality 11.
13. First large bay west of White's Bluff.

		Localities.												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Rhabdammina c.f. abyssorum Brady			6			6	c		c				
2.	Psammosphaera aff. fusca (Schultze)				4					c				
3.	Ammodiscus incertus Stache						1	1						
4.	Haplophragmoides sp. (crushed)	2		1			4	5						
5.	Trochammina ? sp. (crushed)						1	1						
6.	Bolivinopsis cubensis C. & B.			4		3	4	3	2		1			
7.	Spiroplectammina sp.						2							1
8.	Siphotextularia cf. heterostoma (Forn.)						1							
9.	Textularia sp.						2							
10.	Haueslerella pukeuriensis Parr						7							
11.	Karreriella bradyi Cush.							1		1				
12.	Martinottiella cf. communis (d'Orb.)							1						
13.	Gaudryina cf. crespinae Cush.						1							
14.	Massilina tenuis (Czj.)							1						
15.	Sigmoilina n.sp. aff. celata (Costa)				1									
16.	Quinqueloculina spp.				1									
17.	Robulus sp.						3	1						
18.	"Planularia" (auct.) n.sp., (costate)						1							
19.	Saracenaria italica (Defr.)							2						
20.	Astacolus sp.							1						
21.	Vaginulinopsis n.sp.						1	1						
22.	Dentalina aff. consobrina (d'Orb.)	4	1	2			3	1	3		5	1		3
23.	Nodosaria longiscata d'Orb.			2	1	2	c		2		4	1		2
24.	N. pyrula d'Orb.			3		1			2					
25.	N. holoserica Schwager										5	1		2
26.	Lagenonodosaria cf. separans (Brady)						1	1						
27.	L. n.sp.			2										
28.	Chrysalogonium n.sp. (tiny)	1		1	4		3	4	2					
29.	C. n.sp.	1		2	4						2			
30.	C. polystomum (Schwag.)	c		c	c	4		3	3		c	5		c
31.	C. (?) cf. challengeriana (Thal.)						1		2			2		
32.	C. (?) cf. fistuca (Schwag.)			2	4									
33.	C. (?) n.sp.			1										

	Localities.												
·	1	2	3	4	5	6	7	8	9	10	11	12	13
34. Siphonodosaria aff. adolphina (d'Orb.)	2					2							
35. S. aff. jarvisi (Cush.)	c					c	8	6		3			
36. S. aff. alexanderi (Cush.)	4			3		2		4		2			
37. S. n.sp. (tiny, smooth)	5		2	1		5	6	5			1		2
38. S. globulifera (Kreuz.)			1				1						
39. S. cf. bradyi (Cush.)			3	1	1		1	c		1	1	1	4
40. S. sp.			3										
41. Glandulina radicula (L.)						1							
42. Lagena acuticosta Reuss						1							
43. L. hexagona Will.						1							
44. L. hispida Reuss						1							
45. L. hispidula Cush.						1	1						
46. L. striata d'Orb.			1					1					
47. L. orbignyana Seguenza var. A.			1			1							
48. L. orbignyana Seguenza var. B.						1							
49. L. orbignyana Seguenza var. G.						2							
50. L. marginata (W. & B.) var.						2		1					
51. L. cf. meridionalis Wiesner							1						
52. L. cf. fasciata Egger							2						
53. L. sp.						2							
54. L. sp.						2							
55. L. sp. (2 forms)						6							
56. L. elongata Ehrenb.	1												
57. L. semistriata Will.								1					
58. Frondicularia n.sp.			2										
59. F. n.sp. aff. multicostales Fin.				2									
60. Plectofrondicularia awamoana Fin.						1							
61. P. parri Fin.							1	1					
62. P. australis H.A. & E.													1
63. Amphimorphina aff. crassa C. & B.										2			
64. Bolivina anastomosa Fin.						c	5						
65. B. n.sp. aff. anastomosa Fin.					2	c	6			1			1
66. B. lapsus Fin.						c	4			1			
67. B. aff. beyrichi Reuss			2	3	7		3	5		3			
68. B. aff. semialata Bagg			3					c					
69. B. aff. ouachitaensis H. & W.				5				2		1			
70. B. aff. danvillensis H. & W.	c		c	c	c	c	4	c					c
71. B. n.sp.						2	1						
72. Loxostomum n.sp. (common in Mahoenui)	5					c	c						
73. L. hentyanum (Chap.)						6		1					
74. L. aff. delicatulum Cush.						c	c	c					1
75. Rectobolivina maoriella Fin.			1	2		1	4	c					2
76. Virgulina n.sp.						1	1						
77. V. aff. vicksburgensis Cush.			7	1	1	1	5	c					1
78. Virgulopsis n.sp.						1	1						
79. V. pustulata Fin.						3							
80. Uvigerina miozea Fin.						8	2						
81. U. aff. auberiana d'Orb.	4		2		2	4	3	c		1			2
82. Angulogerina aff. oligocenica (Andreae)						2		1					1
83. A. n.sp.					1	2	2	c					
84. A. australis H.A. & E.						c	4						
85. Trifarina bradyi Cush.						c	7						1
86. T. bradyi var.						7	4	2					
87. Siphogenerina rerensis Fin.						5	1						
88. S. n.sp. (tiny)	1		c	1				5					
89. Bulimina truncanella Fin.	1						1	1					
90. B. aff. striata d'Orb.						1							
91. B. aff. pupula Stache.	c		4			2	6	1		1			
92. Cerobertina bartrumi Fin.						1							
93. Cancris lateralis Fin.						1	1						
94. Chilostomella sp.			2							1			
95. Chilostomelloides n.sp	3	3	2	c	5	4	3	1		c	4	1	1

		Localities.												
		1	2	3	4	5	6	7	8	9	10	11	12	13
96.	Pleurostomella sp. A.			1			1	1	3					
97.	P. sp. B.	6		2	7	1	1	1	3		3			1
98.	Nodosarella sp.							1						
99.	Ellipsoglandulina sp.				2									
100.	Ellipsolagena sp.			1	1			1						
101.	E. sp.			1										
102.	Cassidulina subglobosa Brady.						3	1	3					
103.	C. arata Fin.						c							
104.	C. aff. sicula Seg.						4	1						
105.	C. carinata Cush.						4	1	3					
106.	C. sp.						1							
107.	Cassidulinoides orientalis (Cush.)	1		1		1	2	2						
108.	Ehrenbergina n.sp. aff. mestayeri Cush.						2	1						
109.	E. n.sp. aff. osbornei Fin.						2							
110.	Pullenia sphaeroides (d'Orb.)							1			c	1		1
111.	P. subcarinata (d'Orb.)	1									1			
112.	Astrononion aff. australe C. & E.						1	4	c					
113.	A. n.sp. aff. novozealandicum C. & E.						c							
114.	Nonionella zenitens Fin.			3	1				6					
115.	N. novozealandica Cush.			1			8	6	1					
116.	Nonion n.sp. aff. marginatum C. & E.						5							
117.	N. aff. soldani (d'Orb.)						1	2						
118.	Spirillina sp.						1							
119.	Anomalina subnonionoides Fin.						4	2						
120.	A. parvumbilia Fin.						2	2						1
121.	Gyroidina n.sp						2	1	4					
122.	G. aff. zelandica Fin.						c	3			1			
123.	Eponides ecuadorensis (G. & M.)			1	1		2		2		2			1
124.	Epistomina elegans d'Orb.						3							
125.	Parrella n.sp.						2							
126.	P. bengalensis (Schwag.)						3		2					
127.	Alabamina tenuimarginata (C. P. & C.)			1	1		c	1	2					
128.	Pulvinulinella n.sp.							7						
129.	Amphistegina lessoni d'Orb.						6							
130.	Elphidium cf. ornatissimum (Karrer)					1	1							
131.	E. cf. advenum Cush.						1	3						
132.	E. n.sp						1							
133.	Notorotalia spinosa (Chap.)						1							
134.	Cibicides cf. perforatus (Karrer)						4							
135.	C. cf. refulgens Mont.						2							
136.	C. mediocris Fin.						c	3	1					
137.	C. n.sp. A.						5	2						
138.	C. n.sp. B.						c	2						
139.	C. aff. robertsonianus (Brady)						2							
140.	Dyocibicides biserialis C. & V.						c	4	2					
141.	Vagocibicides maoria Fin.						1	2						
142.	Discorbis baconica Haut.						6	5						
143.	D. bertheloti (d'Orb.)							1	1					
144.	D. scopos Fin.						1	1						
145.	D. sp.						1							
146.	D. aff. saulcii d'Orb.								1					
147.	Buningia creeki Fin.						5							
148.	Parvicarinina altocamerata (H.A. & E.)						3	1						
149.	Heronallenia wilsoni (H.A. & E.)							1						
150.	Globorotalia dehiscens C.P. & C.			c	c	c	c	c	5	1	c	3	6	c
151.	G. sp. A.	c		4	6	c	c	c	c	1	1	1	1	c
152.	G. sp. B.					c	5	3	c				5	3
153.	Globigerina n.sp. A.	6	3	c		c	c	c	c		c	c	c	c
154.	G. n.sp. B. (tiny)						5	2			1	1	3	6
155.	G. bulloides d'Orb.			3	6	c	c	3	c	3	3		2	3
156.	Sphaeroidina bulloides d'Orb.						2	2	3					
157.	Radiolaria				2		c	1						
158.	Pteropods						1							

The numbers in the columns are the number of specimens mounted on the slides.

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The Basic Igneous Rocks of Eastern Otago and their Tectonic Environment.

PART IV.—THE MID-TERTIARY BASALTS, THOLEIITES AND DOLERITES OF NORTH-EASTERN OTAGO.

SECTION B:—PETROLOGY, WITH SPECIAL REFERENCE TO THE CRYSTALLISATION OF PYROXENE.

By W. N. BENSON.

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INTRODUCTION.

DESCRIPTIVE PETROLOGY.
- (i) The Pyroclastic Rocks.
  - (a) The Waiarekan Tuffs.
  - (b) The Deborah-Kakanui Tuffs and Breccias.
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    - Monoclinic Pyroxene.
      - Probability of error in Composition-determination.
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    - Anorthoclase Bearing Olivine Basalt.
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APPENDIX I.

Augite, Subcalcic Augite, Pigeonite, and the Classification of Non-alkaline Clinopyroxenes.

APPENDIX II.

The Crystallisation of Pyroxenes. By Dr. A. B. Edwards.

BIBLIOGRAPHY.

LIST OF ILLUSTRATIONS.

INTRODUCTION.

The work recorded herein has been aided by several gentlemen to whom the writer's thanks are due. Of the 120 sections studied (all in the collections of the Geological Department of the University of Otago), 14 were placed there by Dr. Marshall, 3 by Mr. O. D. Paterson, and two were from rocks obtained by Mr. D. A. Brown. Through the courtesy of the Directors of the Dominion Laboratory and of the Geological Survey, five excellent rock-analyses have been made by Mr. F. T. Seelye, A.I.C. Helpful comment on certain petrological points has been received from Dr. A. B. Edwards, of Melbourne, who has very kindly contributed an appendix to this paper, also Professor F. Walker and Dr. A. Poldervaart, of Capetown. Dr. C. O. Hutton has made many measurements of refractive indices. Dr. F. J. Turner has determined on the universal stage the composition of 96 feldspars and 27 olivines and the optic axial angles of 102 pyroxenes, and has most helpfully discussed various problems. But for his generous insistence it would have been appropriate to cite him as co-author of this section.

DESCRIPTIVE PETROGRAPHY.

I.—THE PYROCLASTIC ROCKS.

(a) THE WAIAREKAN TUFFS.

No attempt has yet been made to study the petrographical features of these usually very decomposed rocks. Briefly they consist of moderately fine to coarsely granular material, often richly feldspathic, and contain more or less angular or rounded tachylitic or pumiceous fragments up to an inch or more in diameter, and larger lapilli of vesicular basalt or tachylite. Hutton (1887, pp. 417, 419; 1889, pp. 152–3) has described the more or less altered tachylite, "hydrotachylites," or palagonite from the Mid-Tertiary rocks at Enfield (Teaneraki) and Lookout Bluff (Locs. 105, 84).

(b) THE DEBORAH-KAKANUI TUFFS AND BRECCIAS.

These rocks, first noted by Mantell (1850) and most clearly developed near the mouth of the Kakanui River, were carefully studied by Thomson (1906, 1907), who recorded the presence of large isolated crystals of black or green augite, brown basaltic hornblende and (?) oligoclase, and smaller grains of garnet, diopside, diallage, smaragdite, biotite and olivine; also fragments of (a) more or less limburgitic olivine basalt, sandstone and limestone coming from the Cretaceous-Lower Tertiary formations, (b) argillites from the Late Palæozoic (?)—older Mesozoic rocks immediately beneath them, (c) quartz-mica-schist, granulite, and mica-gneiss from still deeper portions of the upper crust, and

(d) nodules of olivine-augite-spinel, olivine-hornblende-augite-spinel, olivine-augite-brown hornblende-garnet-spinel, augite-spinel, augite-spinel-garnet, augite-garnet with or without hornblende and magnetite, and hornblende-biotite-garnet probably derived from still greater depths in the crust. Most of these types of rock-fragments and nodules were also found by him as xenoliths in basalt. Thomson (1907) compared the last group (d) of rock-fragments and the isolated grains of minerals in the Kakanui tuff with those in the kimberlite breccia of South Africa, or in the ultra-basic rocks of the Ariège complex in the Pyrenees.

The mass of breccia mapped as solid lava by Park (1918), which rises slightly above the general surface of the surrounding Waiarekan tuff a mile east of Round Hill (Loc. 101), probably marks the site of a vent from which Deborah-Kakanui tuff was erupted. It contains a variety of fragments of rocks and minerals, including tachylite (5715), altered olivine dolerite with strongly zoned plagioclase (An_{50-25}) (5715a) and interstitial micropegmatite, which must have been derived from an underlying sill, of greywacke from the immediate basement rocks, and of coarsely crystalline lherzolite (5099) in which, as in that in the Kakanui breccia (6644, 6655), the olivine has been partially replaced by carbonates. Turner (1942) has demonstrated the general lack of marked parallelism of the olivine grains in the fabric of the last rock.

II.—The Massive Igneous Rocks

(Tachylites, tholeiites, basalts and dolerites).

(a) Mineralogical Features.

Plagioclase.

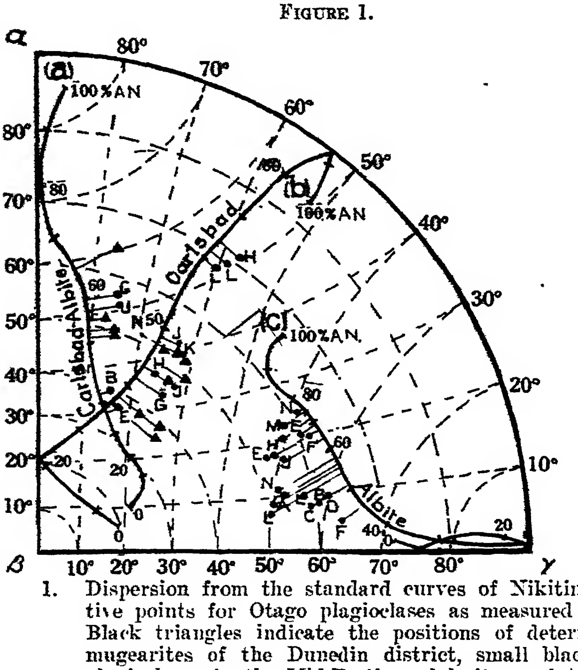
Plagioclase is the dominant mineral. Albite and Carlsbad twinning is commonly associated with pericline twinning and much less so with the twinning on the Ala law. Twinning on other laws has been but very rarely recognised. No attempt has been made, however, to study the occurrence of twinning and to form a judgment as to whether the relative abundance of various types of twinning is a feature of the chemical composition of the feldspar (cf. Barber, 1936) or of the geological mode of occurrence (cf. Chapman, 1936). While phenocrystic tabulae occur in the tholeiites and basalts the tendency towards porphyritic development is diminished or lost in the dolerites, though subordinate interstitial relatively fine-grained plagioclase may occur in them. The larger feldspars are usually free from inclusions other than iron ores and apatite, but in rocks of medium grain-size they are often moulded on or include pyroxene, though the contrasted subophitic relation is more common and very perfect ophitic structure is displayed, especially by rocks in the lower half of the larger sills and in large dykes. Rarely (5878) the outer portions of large plagioclase tabulae contain isolated patches of optically continuous, graphically intergrown augite fraying out into shreds passing through the margin of the plagioclase into the interstitial cryptographic feldspar.

Except in abnormally coarse-grained rocks (see Table VI) the larger plagioclase crystals in tholeiites, basalts and dolerites are tabulae seldom greater than $2 \cdot 5 \times 0 \cdot 7 \times 0 \cdot 5$ mm. and more often

about half that size. Rare instances of early formed crystals, protected from subsequent reactions by inclusion within pyroxenes, may be as calcic as An_{70-68}. More commonly the unzoned or slightly zoned crystals are about An_{57-51}, while those which are zoned have a core of about An_{62-60} occupying the greater part of the crystal and a thin margin of about An_{28}. Where zoning is more marked the margin may be as sodic as An_{20}. Usually, however, before such alkalinity is attained there has occurred a separation of relatively fine-grained interstitial taxitic, trachytic, suborthophyric or cryptographic patches, the plagioclase in which is about An_{40-32} with still more sodic rims. Plagioclase fraying from the marginal zones of phenocrysts out into the fine-grained base has been found in one case (6790) to be about An_{40-38}. Very commonly there is no sharp distinction between earlier and later-formed crystals but a seriate transition through a series of not very zoned tabulae (An_{60-40}).

Dr. Turner's study of plagioclases in these dolerites showed that their determinative points usually fell nearer the standard Nikitin (1936) curves than did those of the plagioclases in such late Tertiary basic igneous rocks in the Dunedin district as the

FIGURE 1.



Rocks Studied in N.E. Otago.

Dolerites

A	=	(5716)
B	=	(5725)
C	=	(5727)
D	=	(5750)
E	=	(5755a)
F	=	(5827)
G	=	(5829)
J	=	(5851)
K	=	(5855)
L	=	(5856)
M	=	(5860)
N	=	(6790)

Tachylite

H	=	(5831)

1. Dispersion from the standard curves of Nikitin (1936) of determinative points for Otago plagioclases as measured by Dr. F. J. Turner. Black triangles indicate the positions of determinative points in the mugearites of the Dunedin district, small black circles those of the plagioclases in the Mid-Tertiary dolerites and tachylite of N.E. Otago. These points indicate:—(a) the directions (points of emergence) of the twinning-axis ⊥ [001] / (010) in Carlsbad-albite twins; (b) the directions of the twinning axis [001] in simple Carlsbad twins; and (c) the directions of the normals to the (001) planes in simple albite twins, each point being referred to the symmetry-axes α, β, and γ of the optical indicatrix of the portion of the crystal examined. The dispersion from the standard curves of these determinative points is shown by their perpendicular distances (thin black lines) from the corresponding curves.

mugearites (Benson and Turner, 1940, pp. 188–199 and fig. 2), though exceptions occur. The general problem involved has received much attention within the last twenty years. Omitting many details we note that Barth (1931, pp. 51–72) investigating albite, oligoclase and labradorite, concluded that the last but not the first two after being heated for 300 hours at 1000° C. showed a displacement of the pole of (010) to an extent estimated by Barber (1936a, p. 351) from Barth's graphical data to be as much as 6°. During a comprehensive study of a wide range of intrusive and volcanic Tertiary igneous rocks in Lower Burma, Barber (1936, pp. 221–258) noted the general dispersion of the poles of plagioclases twinned on various laws along a narrow strip covering one or both sides of the standard Reinhard-Nikitin curves for those laws, and discussing with a wealth of citations the possible effect on such dispersion of observational errors, inaccuracy of standard curves, vicinal deflection of the crystallographic directions of reference, twinning and cleavage planes, etc., and the presence of impurities, notably potash, or physical factors, especially temperature, during crystallisation, concluded that the last has probably by far the greatest significance, the others only slight importance. In his subsequent experimental work on the heating of andesine and labradorite (1936a, pp. 343–352), however, he was unable to confirm Barth's results, and was lead to conclude the variation of the optical properties of plagioclase on heating is very slight and "far too small to be of any value as a geological thermometer." More recently this judgment has been reversed by Continental workers—Köhler (1941, 1942), Scholler (1942) and Tertsch (1941, 1942), who have shown with a wealth of experimental data the necessity of distinguishing between high temperature and low temperature plagioclase. As but brief abstracts of these papers are available at present, tentative comments are withheld.

The plagioclases in the Mid-Tertiary rock are but little altered even when enclosed in deuteric carbonates. No clear evidence of albitisation has been noted, though albite may occur in slight amount among the obscure deuteric alteration products of two analcite-bearing rocks, in which, also, little veinlets of this zeolite have been formed in the plagioclase.

Anorthoclase.

Potassic feldspars can be detected in the general groundmass of a few minutely granular rocks. The normative composition of the feldspar in the five analysed rocks are as follows:—

TABLE I.

Normative Feldspar in Mid-Tertiary Basic Igneous Rocks.

Rock	Type	Locality.	Or.	Ab.	An.
5734	Porphyritic olivine basalt	97	12	52	36
5741	Porphyritic olivine basalt	87	14	49	37
5701	Tachylite	104	9	48	43
5750	Coarse dolerite pegmatoid	83	13	58	29
5860	Ophitic olivine dolerite	83	7	50	43

In Barth's (1936, p. 323) view potassic feldspar must form a phase separate from plagioclase in rocks in which the normative feldspar

contains over 7% of orthoclase, the approximate limit of its solubility in plagioclase. It is noteworthy that untwinned grains of a feldspar with 2 V = 40° (—), which is probably anorthoclase, occurs in rocks (5734) and (5741), and are abundant as idiomorphic tabulae in (5749) analcite bearing olivine dolerite near Maheno (Loc. 96). Anorthoclase is most abundant in what seems to be a pegmatoid segregation (5865) in the same intrusive sheet as that containing the above three rocks—namely, at Waimotu (Loc. 97A). Here it is the dominant constituent of this rock (a basic analcite or melasyenite) and forms Carlsbad twinned tabulae 20 × 1.5 mm. in area, with the shadowy extinction or fine multiple twinning and optic axial angle [2 V = 42°–47° (—) in the plane ⊥ (010)] characteristic of anorthoclase.

In other rocks the alkaline feldspar, if present, is confined to the intergranular spaces either as small tabulae associated with laths of oligoclase-andesine, in trachytoid or orthophyric segregations, or as more or less radiating fibres fraying out into micro- or cryptographic intergrowths, possibly formed by devitrification (cf. Walker and Poldervaart, 1941, p. 136), or into interstitial glass and sometimes extending in optical continuity into a thin zone mantling plagioclase tabulae.

Monoclinic Pyroxenes.

In view of the significance of pyroxene composition in relation to the magmatic affiliation and differentiation of basic igneous rocks special attention was given to the determination of the optic properties of pyroxenes in the granular intrusive dolerites rather than the phenocrystic pyroxenes of porphyritic rocks which Hess (1941, pp. 520, 533) holds to be by comparison therewith rather abnormal. For this purpose 102 measurements of optic axial angles on the universal stage were made by Dr. Turner, and 32 measurements of refractive indices by Dr. Hutton. As noted by Dr. Turner (1942) measurements of the extinction angles ($\gamma \wedge c$) of dolerite-pyroxenes by the ordinary petrographic procedure are subject to considerable error, even when the orientations of the sections examined are shown by observations in convergent light to be favourable for this purpose. Consequently only such extinction angles as have been measured by the most accurate method (Nemoto, 1938) in twinned crystals on the universal stage have been considered. These are very rare among our rocks and only four angles have been thus measured by Dr. Turner. Following Barth's (1931b) assumption that, apart from minor amounts of Al_2O_3, Fe_2O_3, TiO_2 and the alkalies which may be present, the essential composition of the pyroxenes may be stated in terms of $CaSiO_3$ (= Wo), $MgSiO_3$ (= En), and $FeSiO_3$ (= Fs), such compositions have been deduced in the sequel for 45 pyroxenes, some of which are given on Tables IV and VI and plotted on Figures 4, 5 and 6, are stated in terms of molecular percentages in order to confirm with the normal usage of the minals Or. Ab. An. for feldspars. A similar use of molecular proportions is employed in the sequel for the constituent minals Fo and Fa in olivine. This differs from the practice of the Japanese petrologists—e.g., Kunô (1936) and Tsuya (1937), also of Winchell (1927, 1933), and Deer and Wager (1938, 1939), who use weight-percentages in stating the composition of these ferromagnesian minerals. In order to obviate the necessary recalcula-

tion the standard diagram expressing the relationship of chemical composition and optical properties given by Deer and Wager (1938, fig. 2A), based on weight percentages, has been here redrafted (fig. 2B) to show molecular percentages of the three constituent minals.

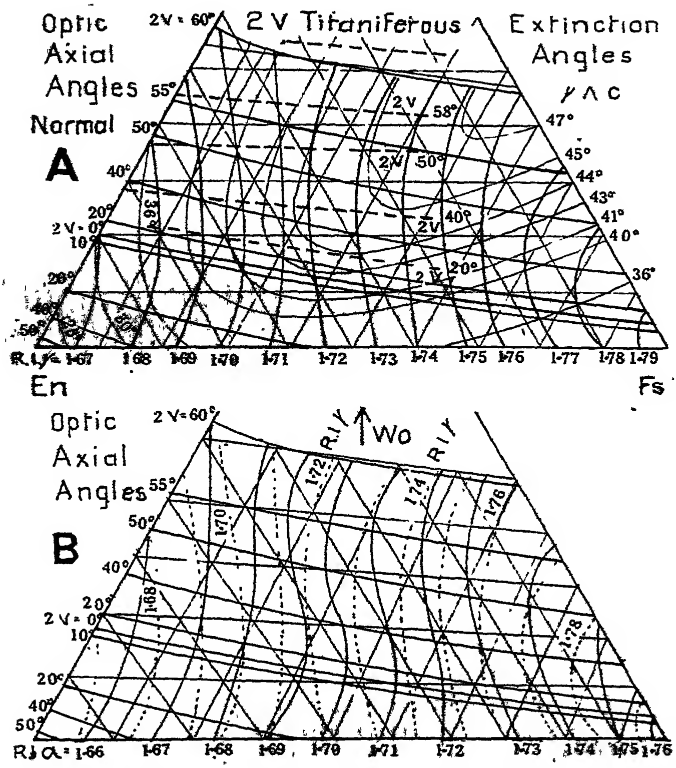


FIG. 2.—Relationship of Chemical Composition to Optical Properties of Clinopyroxenes.

A. Curves of 2 V, extinction angle γ ∧ c, and of refractive index γ after Deer and Wager (1938), also curves of 2 V for titaniferous augites after Kuno (1936) plotted against a background of divisions showing *weight percentages* of Wo, En and Fs.

B. Curves of 2 V and of refractive indices α and γ, after Deer and Wager (1938) plotted against a background of divisions showing *molecular percentages* of Wo, En and Fs.

Probability of Error in the Determination of Pyroxene-composition. (1) Chemical Analysis. Though optical data show the occurrence of a variety of pyroxenes in dolerites, either as separate mineral grains or associated in successive zones in individual composite grains, the differences between the physical properties, especially density, of the several varieties are commonly too small to permit the separation of homogeneous samples, though it has been done under favourable conditions—e.g., by Harris (1937) and Deer and Wager (1938). Hess (1941, p. 579) notes that the original analysis of pigeonite from the type locality is that of an indefinite mixture of augite and pigeonite, each mixed-crystals of variable composition and inseparable,

by mechanical means. Where rhombic and monoclinic pyroxenes are associated, an estimate of the composition of the latter has been determined indirectly by Wager and Deer (1939, p. 76) by estimating optically the composition (2 V determinations) and relative proportions (Rosiwal estimations) of the rhombic portion of the analysed mixed pyroxenes, involving the uncertainties inherent in such optical measurements, but where two phases of monoclinic pyroxene are associated with rhombic pyroxene as in some Antarctic (Benson, 1916), Tasmanian (Benson, 1917; Edwards, 1942), American (Walker, 1940) and African dolerites (Walker, 1940; Walker and Poldervaart, 1941, 1942), chemical determination of the compositions of these several phases is at present almost impossible. Though these last complexities do not arise in the case of our North-East Otago rocks, and it is hoped that subsequently chemical analyses may be made of their pyroxene, for the present the estimations of their compositions have been based wholly on optical data.

(2) Optical determinations. Various uncertainties have been involved in the estimation of the compositions of the pyroxenes from the standard diagram as recorded below, a statement of which is appropriate.

(a) The effect of the presence of an unknown amount of minor constituents on the optical properties of the pyroxenes. Though Winchell (1935, p. 568) showed that variations of the amount of Al_2O_3 " has little effect on the optic axial angles, though a considerable effect . . . on the extinction angle " Kuno (1936) has indicated that the presence of TiO_2 has a noteworthy effect on the optical axial angle, as indicated by comparison of the isogonic curves drawn by Tomita (1934) and Kuno (1936), the latter for augites containing moderate amounts of sesquioxides and titania occurring in Japanese basalts and andesites. (See Figure 2A.) Since for determative purposes Kuno employs the refractive index values of β, which are not available for our rocks, we here follow Wager and Deer, using Tomita's 2 V curves and those of R. I.'s α and γ.

(b) Though repeated measurements of 2 V in favourably oriented sections in Na light would have increased the accuracy of the figures obtained in the present petrographical reconnaissance, single measurements only were made in ordinary light with an average accuracy of $\pm 2°$. Reference to Fig. 2A will show that this possibility of error affects chiefly the estimation of the content of Wo and involves an uncertainty of about $\pm 5\%$ of the total amount of Wo indicated in addition to a general slight under-estimation of this constituent when the Wager and Deer curves are used as here for moderately titaniferous pyroxenes. No correction has been made for this in the estimated composition herein as there is as yet no means for estimating its amount.

(c) The errors $\pm \cdot 003$ in the measurement of the R I.'s α and γ affect chiefly the ratio En : Fs and involve at most a possible error of $\mp 3\%$ En or $\pm 3\%$ Fs, which is halved since two independent determinations are available. The invariably

close composition-estimations derived from the values of α and γ taken singly attest to the accuracy of these optical determinations by Dr. Hutton on our pyroxenes.

(d) Greater possibility of error may arise from the fact that as the refractive indices were determined in powdered minerals in no case were both R. I's and 2 V determined for any particular grain. Since most of the zoned crystals examined show the normal outward *decrease* of 2 V, which in other rock-series has been shown to be associated with outward *increase* in the content of Fs and of the R. I's, the tentative assumption has been made that where the powdered pyroxene in any rock containing zoned crystals shows variation in R. I's the fragments with highest R. I's are those with lowest 2 V and *vice versa,* and that the two compositions estimated from these correlations will show the maximum possible (not necessarily actual) range of composition in such crystals. Figures 3 and 4 have been drafted on this assumption. That it is not far from the truth is suggested by the slight dispersion of points on these two figures.

(e) A further cause for uncertainty may affect our estimated compositions. Krokström (1936) has found that for unzoned pyroxenes in dolerites the optical properties (both 2 V and R. I), and accordingly the chemical compositions, are not uniform, but, as a result of differing rates of diffusion during crystallisation, vary about a mean value in rough accord with a Gaussian curve of error. Variations in the optical properties of unzoned pyroxenes in some of our rocks (e.g. 5880) may have this explanation, though it is difficult to make allowance for it in the case of zoned pyroxenes. The asymmetric frequency-curve for all determined values of 2 V (Fig. 3) is clearly not Gaussian. It is not possible, therefore, to estimate the error that may be involved in the tentative assumption that the various values of the optical properties and deduced compositions of pyroxenes in our rocks represent, not merely such random variations, but stages in the course of pyroxene-crystallisation. It will be noted, however, that such tentatively inferred-differentiation-trends as shown in Fig. 5 are in general in the same direction as the so-called "trends" indicated by the comparison of the compositions of phenocrystic and ground-mass pyroxenes in Japanese (Tsuya, 1937) and other basaltic and andesitic rocks (Barth, 1936).

(f) Determinations of chemical composition based on the extinction angle $\gamma \wedge c$ and 2 V, using figure, 2A have proved, as elsewhere, to be usually very untrustworthy even when, as here, only extinction angles measured by Nemoto's (1938) relatively accurate method. Turner (1942) and others have shown the frequent inaccuracy (up to 5°) of the normal petrographic method of measuring this angle in clinopyroxenes. Apart from this, the usefulness of this method is

affected by the sensitivity of the extinction-angle to variation in the amount of minor constituents in the pyroxene (cf. Wager and Deer, 1939, p. 80), and its equivocal indication for parts of the pyroxene field when only two of the three forms of optical constants are available. The following table (II) gives comparative results for certain Otago pyroxenes:—

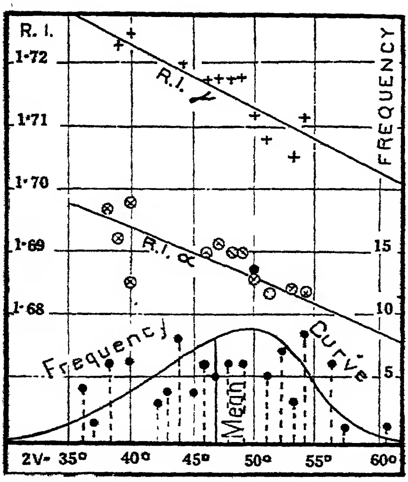
TABLE II.

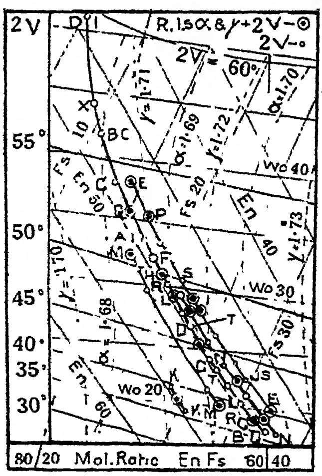
Contrasted Est'mates of Pyroxene-Composition by Different Methods.

Rock	2 V	R. I.	Composition. Wo.	En.	Fs.	$\gamma \wedge c$ (Nemoto)	Composition. Wo.	En.	Fs.
5860	43°	$\alpha = 1.698$*							
		$\gamma = 1.721$*	23	50	27	42 ± 1°	25	58	17
5880	48°	$\alpha = 1.692$							
		$\gamma = 1.718$	29	49	22	41½°	31	55	14
6788	47°	$\alpha = 1.685$*							
		$\gamma = 1.712$*	28	50	22	42½°	30	54	16
6790	55°	$\alpha = 1.685$*							
		$\gamma = 1.708$*	39	46	15	42°	39	47	14

* Probable values of refractive indices estimated by comparison with those of pyroxenes in closely analogous rocks.

As the composition of the pyroxene in (5860), which is optically nearest to that in 6788 above, is normatively Wo_{21} En_{62} Fs_{17} and, as the rock contains olivine, it must be modally richer in Fs than the above, the tendency of composition-determinations based on the extinction angle to under estimate the content of Fs seems to be indicated.





3. Relationship between optic axial angle and refractive indices in clinopyroxenes in N.E. Otago dolerites, etc., also the frequency of occurrence of various values of 2 V.

4. Range of optical properties and deduced trend of composition-variation in clinopyroxenes in N.E. Otago dolerites, etc., expressed in *molecular percentages* of Wo, En and Fs.

While, however, making the above discussed tentative assumptions in this petrographic reconnaissance, an approximation towards a knowledge of the range and differentiation-trend of these Otago pyroxenes may have been gained, the need for more exact observations is obvious. Walker and Poldervaart's (1941, p. 144) conclusion, however, is that " both 2 V and still more $\gamma \wedge c$ are singularly unreliable guides to the composition of pyroxene ". An instance of this may be cited—the carefully investigated phenocrystic augite of the picritic basalt of Haleakala, Maui, Hawaiian Islands (Washington and Merwin, 1922). Apart from 8.5% of sesquioxides, 1.9% of TiO_2 and 1% of the acmite molecule, its essential constituents are Wo_{50} En_{42} Fs_8 as shown by chemical analysis. The composition estimated optically using 2 V and R. I. on Kuno's (1936) diagram is Wo_{50} En_{28} Fs_{22}, and on Deer and Wager's (1938) (Figure 1B) 50:30:20, but that deduced from 2 V and $\gamma \wedge c$ by Figure 2A herewith is 50:8:42.

The Classification of Clino-pyroxenes in Dolerite and Basalt. This has been complicated by the widely varying usage of the term pigeonite, and is discussed in Appendix I to this paper, wherein is suggested the term subcalcic augite for those pyroxenes intermediate in composition between the most calcic pigeonites as commonly defined (i.e., with $2\,V = 45°$) and those with $2\,V < 32°$ (or 30°) to which Hess (1941) and Walker (1941) would confine the term pigeonite. Whether the maximum optic axial angle ($2\,V = 45°$) suggested for the subcalcic augites will prove the most appropriate remains to be seen. It is here selected as coinciding with the limit of " pigeonite " used in its unduly extended sense by most writers. (See Table X.) With the definitions herein adopted the pyroxenes present in the Otago Mid-Tertiary rocks are rarely diopsidic (except when phenocrystic), dominantly normal augite probably containing moderate amounts of titanium and sesquioxides, with noteworthy but subordinate amounts of subcalcic augite with margins approaching the composition of pigeonite, but true pigeonite has not yet been observed in any rock studied. No indication of the presence of exsolved lamellae of orthopyroxene could be found in the clinopyroxenes of N.E. Otago, as is generally the case in rather quickly chilled rocks (cf. Hess, 1941, p. 526). Table V shows the inferred ranges of pyroxene composition in the Tawhiroko intrusive sheet and Table III those in other rocks described herein. The pyroxene-compositions based on the observed optic anxial angle and the asterisked refractive indices inferred therefrom by Figure 2 are naturally less significant than those based on observation of axial angles and both refractive indices. In view of the pigeonitic character of the average normative composition in these N.E. Otago rocks the absence of modal pigeonite calls for discussion which is given on later pages (109–111).

The Trend of Pyroxene-Differentiation. Figure 5 shows the range of composition of the pyroxenes examined plotted from the data given in Tables III and V. To this figure has been added the so-called trend-lines obtained by Barth (1936, p. 327, fig. 2) by connecting the points representing the compositions of phenocrystic and ground-mass clinopyroxenes in basalts from the Pacific, Deccan, Cape

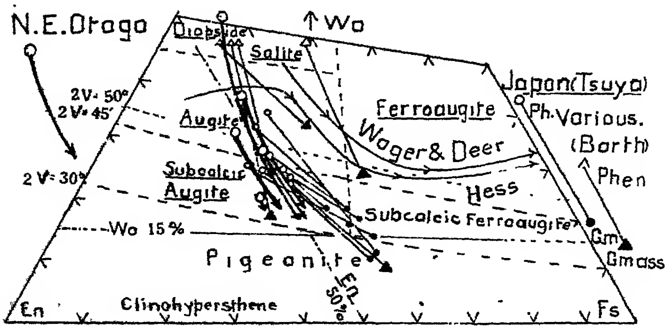
TABLE III.

Optical Characters and Inferred Compositions of Pyroxenes in Mid Tertiary Igneous Rocks of N.E. Otago other than those of Tawhiroko Sheet.

Slide No.	Letter on Fig. 3.	Locality.	Rock Type.	Optics 2 V and $\gamma \wedge c$.	Refr. Indices. α	γ	Composition. Wo	En	Fs
5860	A	Moeraki Main Sheet	Olivine-bearing but over-saturated dolerite	Large Cryst. 52°, 51°.	*1.684	1.711	34	49	17
				Small Cryst. 52°, 51°, 49°, 47°, 44°.	*1.691	1.719	24	50	26
5869	B	Moeraki Main Sheet	Micropegmatitic dolerite without olivine	56°, 54°, 45°, 43° ($\gamma \wedge c = 42°$), 36°, 36°.	*1.680 *1.699	1.706 1.726	41 19	48 48	11 33
5872	C	Moeraki Main Sheet	Coarse olivine-free dolerite with glass	56°, 56° → 44°. 56° → 38°, 46° → 50°§	*1.680 1.690 *1.695	1.716 1.716 1.723	41 19	48 49	11 32
5878	D	Moeraki Main Sheet	Micropegmatitic olivine-bearing dolerite	60°, 50°. 48°, 46°.	*1.677 *1.689	1.703 1.714	50 27	45 50	5 23
5880	E	Moeraki Main Sheet	Coarse micropegmatitic quartz dolerite	54°, 53°, 52°, 48°, 48°, 47° ($\gamma \wedge c = 41\frac{1}{2}°$), 46½°, 44°, 40°.	1.683 †1.692 1.698	1.711 †1.718 1.725	38 28 21	48 48 49	14 24 30
5716	F	North Peak	Richly olivinic dolerite	51°, 50°.	*1.686	1.713	33	49	18
5727	G	Mount Charles	Micropegmatitic dolerite with olivine	54°, 47°. 46°, 43°.	*1.683 *1.692	1.709 1.719	38 23	49 50	13 27
6788	H	Mount Charles	Micropegmatitic dolerite with olivine	49°, 48°. 42° ($\gamma \wedge c = 42–3°$)	*1.687 *1.693	1.713 1.721	30 23	50 50	20 27
6790	I	Mount Charles	Richly pegmatitic dolerite	61–3° ($\gamma \wedge c = 42°$). 56°, 54°, 52°,	*1.679 *1.685	1.703 1.708	50 34	42 48	8 18
		Waimotu	Anorthoclase	57°.	*1.680	*1.705	45	45	10
5865	X	Loc. 97A	Syenite pegmatoid						

* Refractive Indices inferred from 2 V by Figure 3.

§ The only case of "reversed zoning" observed. (For an explanation of the occasional occurrence of "reversed zoning" see Krokström, 1936, pp. 158–9.)



5.—Trends of pyroxene-differentiation (or variation) in N.E. Otago dolerites, etc., compared with those suggested by the differences between compositions of phenocrystic and groundmass clinopyroxenes in Japanese basalts and various other basaltic rocks. Points joined a line representing the compositions of phenocrystic and groundmass pyroxene in the same rock. General trend-lines of pyroxene differentiation deduced by Deer and Wager (1938) and Hess (1941) and the suggested boundaries of the fields of variation of certain pyroxenes (slightly modified) after Hess (*op. cit.*) and subdivisions according to *molecular percentages* of Wo, En and Fs are also indicated.

Verde Islands and Iceland, and also similar "trend-lines" for clinopyroxenes in Japanese basalts and andesites based on data recorded in Tsuya's (1937) excellent and comprehensive work, which contained some of Kuno's (1936) observations. In addition the figure shows the general trend of pyroxene-differentiation inferred by Wager and Deer (1939) for ferriferous gabbros in the Skaergaard, E. Greenland, and by Hess (1941) for basic igneous rocks in general. It will be noted that with the exception of the calcic portion of Hess' diagram (cf. Edwards, 1942, p. 600, fig. 17) these two generally arcuate trend-lines are approximately parallel to those shown by Barth's, Tsuya's, and our pyroxenes. The last show a further point of interest. Though Hess excluded the phenocrystic pyroxenes from his general discussion of pyroxenes on the ground that they were abnormal in their highly calcic composition and in other ways, it is doubtful whether, in the general absence of phenocrystic pyroxene from the tachylitic margins of dolerite sheets, we may suppose the invading magma contained such plutonic crystals. The strongly calcic pyroxenes D and I (Fig. 4) in the coarsely crystallised micropegmatitic dolerite of the Main Moeraki sheet and Mount Charles may, perhaps, therefore, have been wholly autochthonous. The early differentiation-trend as the lime-content falls from Wo_{50} to Wo_{40} involves a replacement of Wo by En and Fs in the proportion of about 1:2. Beyond this Wo is replaced by Fs only, the composition being expressible approximately by $Wo_{(x)}En_{(49)}Fs_{(51-x)}$ over the range x = 35 to 18, En remaining approximately constant (cf. Barth, 1931, p. 208). The replacement of both Wo and En by Fs beyond this limit is indicated by Wager and Deer's and Hess' curves. Dr. A. B. Edwards has discussed the significance of clinopyroxene trends in terms of ionic radii and lattice structure in an appendix (II)

kindly contributed to this paper. The explanation of the trend exhibited in our rocks is, as Edwards indicates, probably the rate of cooling, the production of metastable clinopyroxenes in the more rapidly cooled rocks such as our relatively thin intrusions (see p. 119) and the volcanic rocks, while with slower cooling and greater approach to molecular equilibrium the trend towards concentration of iron sets in earlier during " plutonic " crystallisation.

The clinopyroxenes are generally free from decomposition though locally partially replaced by carbonates and chloritic minerals, a process affecting finely granular ground-mass pyroxenes more than phenocrysts. Only rarely are the larger pyroxenes partially replaced by deep green chlorite as in two olivine dolerites (5887-8) and the Waimotu syenite-pegmatoid (5865). There is no *clear* evidence of deuteric uralitisation. (See below.)

Orthorhombic Pyroxene.

Orthorhombic pyroxene referred to enstatite (though displaying the pleochroism of hypersthene) has been noted by Hutton (1887, p. 428) in the dolerite of Mt. Charles, but has not been observed in slides from there examined by the writer. Apart from this occurrence, rhombic pyroxenes are not present in the normal tholeiites basalts or dolerites; nor could there be recognised in any of these features suggesting the presence of remnants of orthpyroxene surviving incomplete transformation to clinopyroxene. Hypersthene does occur, however, in basic rocks which have absorbed silica from quartzose xenoliths as Lacroix (1893, p. 34, Harker (1904, p. 353), and others have noted, and instances will be noted in the discussion of endo- and exomorphous metamorphism at the margins of intrusions in Section C of this paper. Whether or not this is the explanation of Hutton's observation remains to be determined.

Hornblende.

Hornblende has been found in a quartz-dolerite (5891) where it occurs either in short (0·4 x 0·3 mm.) or long (2·0 x 0·2 mm.) prisms,, or in small scattered fibres. Its pleochroism varies, pale to stronger yellowish brown tints occurring in the course of the larger grains, pale to stronger yellowish to bluish green in the outer portions, and in the fibres the latter is a common though not invariable rule. Occasionally, where greenish fibres cross a band of limonitic decomposition products, they assume a brown coloration, and the same may hold in the proximity of the iron ores, but exceptions occur here also. As the pyroxene in this rock is perfectly fresh, without sign of uralitic alteration, and in the two cases where a close association of pyroxene and amphibole has been noted, the vertical axes of the two minerals are oblique to one another, it seems possible that the latter is the result of independent crystallisation, though its composition has been affected by deuteric processes. The variability of its colour accords with what is usual under such conditions (cf. Walker, 1941, p. 1076). It contains apatite, but is enclosed in feldspar, into which, however, may penetrate tangled or sub-radiating fibres of amphibole distributed by deuteric processes,

Olivine.

Olivine is usually the most abundant and often the only coloured phenocryst in porphyritic rocks. It forms in these crystals up to 3 mm. long though usually less than half this size. In the hypocrystalline rocks it is usually idiomorphic, in those with a basaltic matrix it may be more or less corroded, with (5741) or without the development of a reaction-mantle of minutely granular augite. As is commonly the case, the larger phenocrysts are usually richly magnesian and slightly zoned, though the smaller phenocrysts (5741) may show marked zoning (cf. Walker, 1941, p. 1068). Sometimes a second generation of ground-mass olivines has been formed. The more coarsely granular olivines of the dolerites have sometimes broad zoning with a small range of composition. Comparison of normative and average modal composition of the olivine is afforded by the following table:—

TABLE IV.

No.	Rock Character.	Norm.	Mode.
5734	Porphyritic sparsely olivinic basalt	Fa_{31}	Fa_{3} (Average)
5741	Porphyritic richly olivinic basalt	Fa_{20}	Fa_{23} (Average)
5860	Slightly over-saturated olivine dolerite	Nil	Fa_{25} (Average)

The olivine in (5734) has a nearly uniform composition, two unzoned crystals being Fa_0 and Fa_8. A zoned crystal has a core of Fa_2 with a thin mantle of Fa_{13}. Olivines in (5741) are more variable; wide zones show core → margin $Fa_{10\text{-}24}$, $Fa_{28\text{-}38}$, and $Fa_{33\text{-}50}$; narrow zones show $Fa_{5\text{-}13}$, and in an unzoned crystal Fa_{28}. In both these rocks the average modal olivine is (as usual) more forsteritic than the normative. In (5860), which contains normative quartz, comparison can be drawn only between the Mg/Fe ratios in the modal olivine (Fa_{16}, Fa_{30}, Fa_{30}) and in the normative hypersthene ($Fs_{21.5}$).

The gravitational concentration of coarsely granular olivine into the lower portions of intrusive sheets and the retention of only a little of the slowly sinking smaller grains in the upper portion is well displayed at Tawhiroko Point (Fig. 6) where, however, complete decomposition prevents any estimate of the original composition of the olivine.

The most abundant decomposition product of olivine is weakly pleochroic rather strongly coloured brownish-green bowlingite, occasionally associated with pale green chrysotile, and less often so strongly coloured by absorbed iron oxides that it resembles (and perhaps is) iddingsite. With these silicates are varying proportion of carbonates. In some cases these are in radiating aggregates (sphaerosiderite) or more coarsely crystalline masses of siderite which on weathering form massive or pulverent haematite. In others calcite may be associated with the siderite. Both of these may occur with varying amounts of chalcedony or quartz as a fine-grained mosaic or plainly pseudomorphous after chrysotile, and with these residual bowlingite remains. Some replacement of olivine by talc has occurred in a few rocks. Rarely (5878) talc forms much of the pseudomorph.

Iron Ores.

Ilmenite is often the more abundant iron ore. In the more coarsely granular rocks it forms thin plates (2·5 x 0·1 — 0·3 mm.), though usually it is proportionately smaller. It is moulded on olivine and rarely on pyroxene and feldspar, with the former of which it may be intergrown. More often it is idiomorphic against both pyroxene and feldspar. In places a group of parallel plates of ilmenite may extend through the rock for several millimetres, to five times the length of any one plate in the group. Rarely a thin reaction-mantle of biotite covers the ilmenite where it extends into micrographic intergrowths or among deuteric minerals. In a few more altered rocks leucoxenisation of the ilmenite is seen as Hutton (1887, p. 428) noted at Mt. Charles, and the presence of lamellar intergrowths of titano-magnetite becomes observable (5891). In some coarsely granular dolerites, but more often in those of medium to fine grain size, approximately octahedral magnetite is abundant, and rarely minute octahedra occur in the phenocrystic olivine.

In glassy material, and among the feldspathic intergrowths developed therefrom, minute plates and skeletal growths of ilmenite and tiny octahedra of magnetite, either isolated or in dendritic aggregates, may be found, and a frequent feature is the development of minute magnetite octahedra studded at intervals along the augite-microlites. In general the proportion of iron ores to ferromagnesian silicates increases with the feldspathic content of the rocks and towards the middle of intrusive sheets, but only a qualitative significance in this regard can be attached to Fig. 6. Barth's (1931, p. 393) comment, " based on textural features, that under certain circumstances the ore minerals crystallise early, but usually relatively late, though not as late as the bulk of the alkali feldspars and quartz," seems to hold good.

Phemister (1934, pp. 40–44) has argued that the state of oxidation of iron in magmas may be affected by the reversible reaction $3FeO + H_2O \rightleftharpoons Fe_3O_4 + H_2 + 15{,}400$ calories, and that since hydrogen can escape more easily than water-vapour through the pores of wall-rocks, the ratio $Fe_3O_4:FeO$, and, therefore, the amount of magnetite developed proportionately to that of other ferriferous minerals crystallised will tend to be increased by the exothermic reaction during the later stages of magma-cooling, when the expulsion of gas is most rapid. The pyroxene formed concommittantly therewith will accordingly tend to contain En in greater proportion to its Fs than would occur if no such oxidation took place. This process may be exemplified to some extent by the rocks, especially (5855) and (5750) of the Tawhiroko sill (Fig. 6) as well as in those cited by Phemister.

Biotite.

Biotite is rarely developed save as a product of reaction between iron ores and micropegmatite. It is, however, present in small (< 0·05 mm.) rare flakes in a few of the more potassic rocks—e.g., the anorthoclase-bearing basalts (5734, 5741), and more abundantly in analcite-bearing dolerite (5749) occurring a mile west of Maheno, and very abundantly in a coarsely granular basic anorthoclase analcite syenite-pegmatoid (5865) at Waimotu, two miles S.S.W. thereof (Locs. 96 and 97A respectively). In the latter rock it has been largely replaced by chlorite.

Apatite.

Apatite, generally present in small amounts only, occurs in thin needles in the feldspars, and is chiefly concentrated in the interstitial crypto- or micrographic material. There is a noteworthy difference between its scantiness in the Tawhiroko Sheet and its greater abundance in the upper portions of the main Moeraki Sheet, both in the larger feldspars (where the needles may be 1 mm. long) and in the interstitial material. It is especially abundant in the analcite syenite. In the more finely granular rocks it occurs in small amount only, and is not always recognisable.

Quartz and Chalcedony.

Quartz occurs chiefly in interstial intergrowths, and its presence there is inferred chiefly from its refractive index. It is rarely present in the Tawhiroko rocks in granules large enough to display other determinative properties, though occasionally the quartz fibres in the intergrowth may be traced out into characteristic granules. Its concentration into the part of this sheet immediately below the upper chilled phase accords with experience elsewhere (cf. Walker, 1941, p. 1075). This is much more evident in the higher rocks of the thicker main sheet, where it appears in several forms; (a) as irregular grains up to 0·1 mm. diameter between feldspar tabulae not directly associated with interstitial intergrowths, though sometimes continuous with the quartz fibres therein, or (b) as direct continuations of such fibres extending towards the central portions of the larger interstices and there uniting into larger grains with crystal-boundaries particularly obvious in the case of hexagonal basal sections against which the ferruginous carbonates are moulded. Such more or less idiomorphic quartz may include small apatite needles and rarely anorthoclase (?) microlites, and may only occasionally show marginal undulose extinction. Where, however, a later generation of quartz occurs separated from the former by ferruginous carbonates or "chlorite," undulose extinction is generally observable, and in some rocks (e.g., 5890) the quartz is divided into radial sectors each having its vertical crystallographic axis parallel to its length.

Chalcedony may rarely (e.g., 5878) form a very thin mantle on quartz with fibres growing perpendicularly to the prism faces which it separates from the surrounding carbonates. More commonly, however, it occurs in radially fibrous nodules within such carbonates (as in 5869). In other cases (e.g., 5722) chalcedony forms irregular patches replacing interstitial glass, and formed, as Fenner (1931) indicates, as a by-product of the change of glass to chlorophaeite. Probably as Tomkieff (1941) notes the chalcedony and the radial and undulatory quartz first consolidated as colloids. Rarely a little opal is still observable.

In addition to these forms of silica there are occasionally thin or irregular veins of finely granular calcite and chalcedony traversing the massive dolerites, and probably derived from an extra-magmatic source—namely, the invaded marly sediments (cf. Leitmeier, 1909).

The Otago dolerites do not seem to afford any clue to the problem of the magmatic or deuteric origin of the micro- and cryptographic interstitial quartz-feldspar intergrowths. The observed features appear consistent with the former view, though Fenner (1926, 1931)

held that it is hardly safe to assume such an origin, and that these intergrowths are often the result of post-magmatic replacement of feldspar, etc., with which Walker (1940, p. 1093), modifying his (1930) former view, is now in agreement.

Zeolites.

In the anorthoclase syenite-pegmatoid (5865) of Waimotu analcite forms abundant intergranular masses (< 2 mm. in diameter) moulded on the feldspars, and small, almost rectilinearly bounded patches surrounded by chlorite which suggest an originally idiomorphic development. It is associated with a little carbonate which also occurs idiomorphically in radiating spherules of natrolite which, together with analcite, fills one of the vesicular (?) spaces. Analcite also replaces feldspar to a slight extent. It is rare in other rocks, though forming sparse, small (< 0·5 mm.) patches or thin veinlets in plagioclase in the more finely granular part of the same intrusion extending to Maheno (5749). A little stilbite (?) seems to be present in the olivine basalt of Lookout Bluff (5752).

Chlorophaeite and Carbonates.

Chlorophaeite and other chloritic minerals range from very pale green finely flaky or fibrous material with weak birefringence and pleochroism [delessite (?) or "green chlorophaeite" of Peacock (1930) and Fenner (1931)] to dark greenish yellow or brown or more deeply coloured brownish ferriferous aggregates—both weakly birefringent or isotropic chlorophaeite or possibly diabantite where strongly birefringent (Shannon, 1920, 1924). The less deeply coloured but strongly birefringent mineral is possibly chlinochlore. These substances occur with radiating fibrous carbonates, usually coating the surfaces on which the latter were subsequently deposited, though they may also occur coating such carbonates. Such variations of the order of deposition of the pale or highly coloured hydrous silicates are to be seen both replacing olivine, groundmass-augites or glass, and in vesicles.*

The deuteric carbonates are also varied in nature and position. The earliest formed were usually siderite, replacing ground-mass—or rarely phenocrystic augite, but more commonly glass. They also occur with the interstitial cryptographic aggregate, and are so abundant that few rocks can be chosen as appropriate for chemical analysis or density-determination. Both granular and radiating patches occur often stained scarlet by oxidation (e.g., 5750). Where calcite or aragonite is present it usually crystallised after the fer-

* Tomkieff (1942, pp. 10–12), citing comments by Loewinson-Lessing, Backlund and Sazonova, has suggested in regard to the trachybasalts of Rum, which contain amygdaloidal portions rich in silica minerals, chlorophaeite, celadonite and carbonate, that these rocks are possibly solidified macro-emulsions which show incipient stages of separation into possibly immiscible "dry" and "wet" fractions. "The wet fraction on further cooling gave rise to the amygdaloidal material, which, as judged by the minerals developed in it, such as opal and chlorophaeite, was of the nature of a gel." He notes, however, that the hypothesis does not apply "to all amygdaloidal lavas, which in many cases may be formed by the infilling of vesicles by late-magmatic or hydrothermal products." It seems most likely that the rocks here described fall into the latter group.

ruginous carbonates perhaps because of the greater solubility of $CaCO_3$ (cf. Tomkieff, 1941, p. 56). Some vermiform masses of radial siderite (?) are present in large calcite crystals replacing either olivine (?) or the general interstitial matrix.

Glassy Material.

Glassy material occurs in several modifications. At the chilled margin of the pillow lavas (e.g., 5701, Analysis No. 1, Table VII) it is pale yellow and transparent, with R.I. 1·5772 ± 0·0002 and sp. g. 2·725, figures which, according to the investigations of Tilley (1922) and George (1924), are consistent with a content of 51–53% of SiO_2, agreeing well with the analytical result 52·92%. Since the density calculated from the norm (Washington, 1922, p. 387) is 2·965, there will be a volume contraction of 8·7% in completing the crystallisation of the glass which contains small labradorite laths and grains of forsteritic olivine. Similar glass is formed in the chilled margins of intrusions, and is either pale brown or almost colourless (5831, see fig. 6, 5883), or so crowded with dustlike particles of iron ore as to be dark grey or almost black (5833, 5839, 5881). It may contain innumerable minute microlites of labradorite, some of which have skeletal extensions, or tabulae up to 0 5 mm. long, together with small pseudomorphs after olivine and crystals of augite ($2V = 46°$ — 42° in 5831).

Interstitial glass in the more finely granular olivine tholeiites is similarly either clear pale brown with or without dustlike or minutely platy iron ores locally in skeletal aggregates, and lathy or rod-like microlites of feldspar or augite, or it may be darkened by aggregations of particles of iron ore and pyroxene either enclosing the feldspars or occupying the whole mass of glass.

In vesicular rocks, the melt, while stiffening around the vesicles and giving rise to crystallites of iron ores, feldspar and pyroxene as described above, may have been squeezed in droplets into the cavity of the vesicles as the vapour pressure therein diminished (e.g., 5871), the remaining space being filled later by deuteric minerals, or the vesicles may be completely filled by dust-darkened glass containing abundant plagioclase microlites (e.g., 5743). All stages in the filling of vesicles by partially crystallised residual magma may be seen in a single rock (e.g., 5875). Features similar to these in British tholeiites were long ago noted (Teall, 1889). In some rocks (e.g., 5885), the residual magma was squeezed into vesicles before cooling was far advanced, and crystallised wholly or partly into platy ilmenite, thin augite prisms and lathy andesine. In other rocks (e.g., 5743), residual glass remains in the vesicle, but has a much lower refractive index (1·508) than the quickly chilled marginal tachylite glass. Again, in a coarsely crystalline dolerite high in the main Moeraki Sheet (5872), (in which cryptographic intergrowths might be expected), the interstitial material is a very pale brown partially devitrified glass containing microlitic oligoclase, augite and iron ore, and has a refractive index varying from 1·489–1·500 but usually 1.497. If these glasses were anhydrous the refractivity would suggest for that in (5743) a content of about 68% SiO_2 and for (5872) about 72% SiO_2. In view of the observations of Washington (1922, pp. 770–2) and Fenner (1931, pp. 556–7) it is more likely that

the lowered refractivity and paler colour results from the deuteric hydration of the residual glass.

(b) The Pillow Lavas and Associated Basalt Flows.

The tachylitic margin of the pillow lava at Boatman's Harbour and Awamoa Creek [Locs. 101, 102, slide (5701) = Anal. 1, Table VII, and (6794)] is pale yellow and transparent, and contains many small (< 0 4 mm.) unzoned laths of labradorite (An_{69-60}) and granules (< 1·0 mm.) of almost forsteritic olivine ($2V = 84° — 86°$). The darkening of the glass around the feldspar microlites by the abundant development of dusty magnetite and pyroxene-crystallites, and the gradual individualisation of these with advancing crystallisation may be traced in slides (6795-6) intermediate between the margins and centres of the pillows, and resemble the features described by Rosenbusch (1908, pp. 1276–80) as typical of such crystallisation to a greater extent than they do those noted by Fenner (1910) in the pillowy phase of the Watchung basalt. In the centre of a small pillow (6797–8) the plagioclase (An_{62-60}) forms slightly zoned tabulae (< 1.0 mm.) and may have skeletal outgrowths. The associated microlites may be as sodic as An_{42}. The glass is locally coloured red by swarms of minute deep brown translucent and opaque rods which, though not determinable (cf. Rosenbusch, 1908, p. 1278), suggest microlites of titanaugite. With these are minute skeletal iron ores. The glass is partially decomposed to pale yellow palagonite, or chloritic substances associated with a little indeterminate zeolite. Sometimes, as in the pillow lava (5868) in the Totara cutting, the vesicles have a thin lining of clinochlore. Pseudomorphs after olivine crystals are larger and more abundant in this rock than in those first cited.

In the centre of a larger pillow (18 x 12 ft.) at Awamoa Creek (Loc. 102, 5753) crystallisation is more advanced. The rock is a normal olivine tholeiite* not unlike the British Salen and Brunton types (Holmes and Harwood, 1929, pp. 12–17, Plate 1, Figs. 1–2). The larger feldspar crystals, about 1·0 mm. long, with olivine pseudomorphs are set in a matrix of labradorite tabulae with granular or subophitic augite ($2V = 52°, 54°$) and more or less altered interstitial glass. This stage of crystallisation is represented by a rock (5725) in tuffaceous greensands beneath Waitaki limestone, near Tokarahi, 19 miles north-west of Oamaru.

(c) The Dykes of the Moeraki Peninsula.

The thinnest of the dykes (e.g., 5883) invading the Waiarekan breccia are tachylitic, containing decomposed phenocrysts of olivine, fresh crystals of labradorite and augite in a vesicular pale brown glass. Similar material, much richer in magnetite dust, forms the selvedges of the larger dykes and the thin dykes (5839) invading the Tawhiroko sheet, the matrix of which is almost opaque. (See Fig. 7.) The central portions of the majority of the dykes, including that forming the prominent outcrop at Te Paitu (5875), are vesicular olivine

* The term tholeiite is here employed as by Rosenbusch (1908, p. 1224) to denote hypocrystalline doleritic rock with intersertal structure. The relation of the Otago tholeiites to those in which recent British authors, especially Kennedy (1931, 1933), have recognised distinctive chemical features, is discussed below.

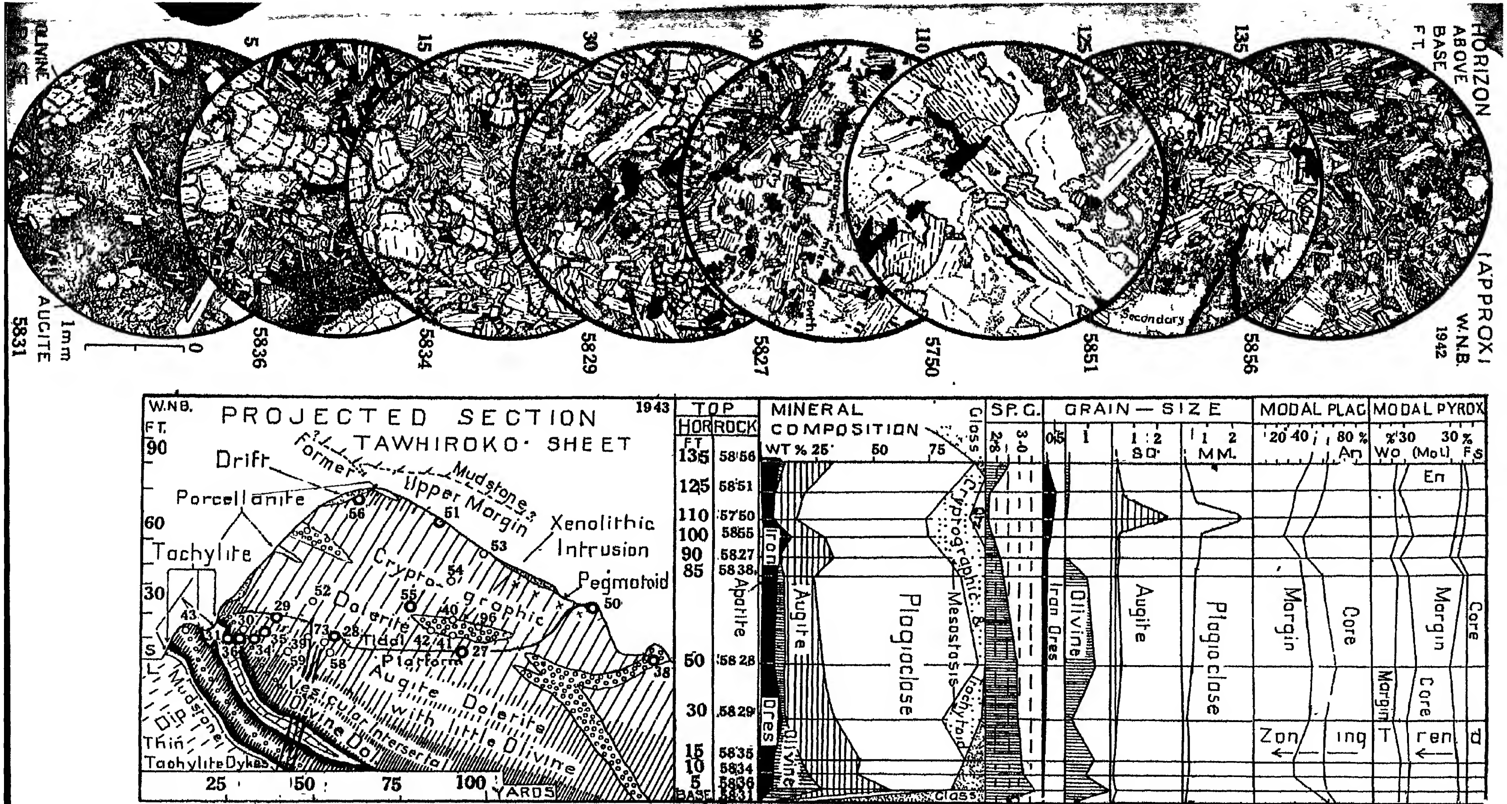
tholeiites of rather fine grain-size, with irregular or subradiating labradorite tabulae, granular to sub-ophitic augite, platy and less often octahedral iron ores, and interstitial glass occurring in varying amount (5842, –48, –70, –71, –85). Rarely glass is lacking from the middle portions of the dykes, and the rock is in consequence a fine-grained olivine dolerite (5857). Most of these dykes contain siliceous xenoliths, the features of which will be studied in Section C of this paper.

Less finely granular but more ophitic and non-vesicular are the olivine tholeiites forming the thick dyke a quarter of a mile west of Te Koraki Point (5876), which is horizontally columnar, and that by the railway line a mile south of Trig. E (5832). In both of these there is but little interstitial glass. The rock forming Moeraki Point (5751) is a medium grained non-vesicular sub-ophitic olivine dolerite. That forming the largest dyke running W.S.W. of Te Koraki Point (5877) is noteworthy for its coarseness of grain-size, absence of olivine, and presence of a noteworthy amount of interstitial glass containing radial feldspar microlites, and other products of devitrification and deuteric alteration. It is closely similar to the rock (5872) forming the higher portion of the main dolerite sheet above Matiaha Head.

(d) THE TAWHIROKO INTRUSIVE SHEET.

This forms one of the most complex examples of gravitational differentiation studied in New Zealand†. Its main petrographical features indicated in Figure 6 (Benson, 1943) are revised in Figure 6 of this paper, also Figure 7 and Table VI herewith. It invades the Tahuian mudstone cutting obliquely across the stratification plane. The disposition of the various differentiates suggests that, though the western margin rises steeply through the sediments, the mass as a whole has a gentle eastward dip. As the angle of slope cannot, however, be measured or estimated, and the upper margin has been eroded away, its original thickness cannot be determined precisely, but was about 150 feet. Wave-erosion has produced a tidal platform about 8000 square yards in area, whereon the complex features of the lower half of the sheet may be studied in detail. Those of the upper half may be seen less completely in the low cliffs bounding the platform and the grassy hill slopes above. Little need be added here to the information afforded by the illustration and descriptions of the geological relations of the igneous rocks to their environment given in Section A of this paper. In regard to the data on Figure 6 it should be noted that the drawings and estimations of the proportions between the several minerals are based on inference as to the original character of the rocks prior to their deuteric alteration and weathering. They cannot be considered as more than qualitatively accurate, since in view of the abundance of secondary products often distributed beyond the limits of the parent substances, and the occasional difficulty of distinguishing between those derived from glass and those derived from

† Attention may be called to Marshall's (1906) account of the association of lherzolite, pyroxenite, gabbro, and diorite at the Cow Saddle, in the region difficult of access north-west of Lake Wakatipu, which suggests the effect of gravitative differentiation in plutonic rocks, and is well worthy of fuller investigation.



6. Petrographical features at successive approximately estimated horizons in the intrusive dolerite sheet of Tawhiroko Point. The positions of rocks illustrated are indicated by thick circles on the projected section, that of other described rocks by thin circles. The attached numbers are the *last two* digits in the register-numbers of the corresponding rocks in the catalogue of the Geological Museum of Otago University. Except in the case of 5743 and 5750 the *first two* digits are 58.

olivine or augite, micrometric studies seemed hardly justified. Recourse was, therefore, made to the method of estimation by inspection, with the help of Holmes' (1921, p. 324) diagrams, the areal proportions of the several minerals in not less than 12 quadrants (sixteen or twenty for more coarsely granular rocks) of fields of view selected as typical, and calculating weight-percentages from the

Rock Slide	Index Letter Fig. 4	Plagioclase: Estimated Height Above Base Ft.	Plagioclase: % of Anorthite (Univ. stage)	Pyroxene: Optic Axial Angle	Pyroxene: Ref. Indices α	Pyroxene: Ref. Indices γ	Composition Wo	Composition En	Composition Fs
5856	J	135	Large crystals 62 → 50 → 47, 58 → 50. Small crystals 59, 55 ± 5.	49° → 43°, 44°.	1.690	1.718	Core 30 Margin 23	 47 47	 23 30
5851	K	125	59, 48 → 43 ± 2, 44 → 35 ± 2.	40° ± 3°, 38° 37 ± 3°, 36°.	1.685	1.711	22 19	55 55	23 26
5750	L	110	Large 49, 48, 45, 40 → 34, Small, 32.	48° 45° → 40°	1.690	1.714 1.718	29 22	49 48	22 30
5855	M	100	45 → 36, 39 → 27.	51°, 48°, 40°, 39°.	1.683 1.692	1.708 1.721	32 20	51 52	17 28
5827	N	90	39, 38, 37 ± 2.	44° ± 3° 38°	1.698	1.721 1.723	25 19	48 49	27 32
5838	P	85	58 → 40, 57, 51.	52°, 50°, 49°.	1.685	1.712	33 30	49 50	18 20
5828	Q	50	69 → 45 (thin zone), 63, 59, 56, 55 ± 3.	53°, 50°, 50°, 38°	1.684 *1.696	1.705 1.710 1.715	36 18	50 50	14 32
5829	R	30	49, 46 ± 3, 44.	50° → 38°, 46°	*1.686 1.697	1.713 1.723	31 19	49 50	20 31
5835		15	58 → 30.	—	—	—	—	—	—
5834	S	10	62, 60, 60 → 50.	50°, 50°, 48° 48°, 44°, 43°	1.690	1.718	30 23	50 50	20 27
5836		5	60 → 48.	—	—	—	—	—	—
5831	T	0	64, 63, 61.	46°, 44°, 42°	*1.689 *1.693	1.716 1.720	26 22	50 50	24 28
5743		Spur	60, 60, 44 lath.	54° 49°	1.683 *1.687	1.710 1.715	38 30	48 49	14 21

* Refractive indices and compositions estimated from 2 V by Figs. 3 and 4.

averaged areal proportions of the several minerals of known composition the densities of which were obtained from Washington's (1922 pp. 586–7) table, the glass being assumed to yield crystalline material with an average sp. g. of 2·90 (or 2·95 in the more basic rocks). The densities of the Tawhiroko rocks calculated from the above data, on the assumption that they were water-free holocrystalline and non-vesicular, give the curve plotted on Figure 6, and afford an indication of the extent of gravitative differentiation.

Finally, it should be noted that the projected section of the Tawhiroko sheet is a slight modification of that given as Fig. 6 of Part A of this paper. The thickness of the possibly lensoid intrusive-sheet is not available as it is very irregular and transgresses the bedding planes of the invaded formations. The elevation of the various specimens above the base of the sheet is not known with certainty, and the relative levels of 5827, 5828, 5838 and 5855 are also not quite certain. The "estimated heights" given in Table V and Fig. 6 are thus rather hypothetical.

The spur from the base of the main sheet and the base of the sheet itself have tachylitic selvedges less than an inch thick (e.g., 5831), containing phenocrysts of almost unzoned labradorite, olivine and very subordinate augite set in a pale brown glass containing feldspar microlites and dusty or skeletal iron ore.

Less than five feet above this is vesicular olivine-tholeiite (5836-7) with nearly homogeneous tabulae of labradorite sometimes moulded on the gravitationally segregated olivine (which is here in greater amount than in any other part of the Tawhiroko sheet), and more abundant but smaller idiomorphic to subophitic augite and minute granules plates or skeleton-crystals of iron ores and feldspar microlites in glass which occurs interstitially and in sheets 0·5 mm. thick around the vesicles. Xenocrysts of quartz occur surrounded by the usual reaction-rim of minutely prismatic augite.

About ten feet above the base is the first aggregated band of such xenoliths (5825–30) to be described in Section C of this paper. The enclosing rock (5830) is similar to (5743) the middle of the basal spur, which in turn is similar to the rocks of the Te Koraki Point dyke (5742, 5748) and is probably continuous therewith. Both the basal spur and this dyke contain quartzose xenoliths. Crystallisation of these tholeiites is further advanced. Glass still remains about the vesicles but is less abundant in the general ground-mass, where is augite in thin prisms studded with crystals of magnetite. Here and there are small ($< 2·0$ mm.) patches of ophitic pyroxene. Olivine crystals are naturally smaller ($< 1·0$ mm.) and rather less abundant in the spur and dyke than they are in the main sheet (5830) because of their gravitative accumulation therein. The plagioclase is now well zoned and on the whole a little more sodic. Radiating carbonates with subordinate delessite (?) fill the vesicles (5830) or replace glass (5743).

A few feet above this xenolithic band olivine has decreased in abundance, but a little glass is present save about the vesicles, where it has the usual decomposition products (5755, 5834–5). The probably hydrated glass has R.I. = 1·508 (see p. 89). The bulk-density

of the rock (2·83) is less than normal for a holocrystalline, non-porous unaltered rock of this composition. Its texture approaches that of rather finely granular ophitic dolerite. This texture is more pronounced in (5858-9) and (5873) beyond the northern end of the xenolithic band, which rocks contain vesicles wholly or partially filled with more or less devitrified glass.

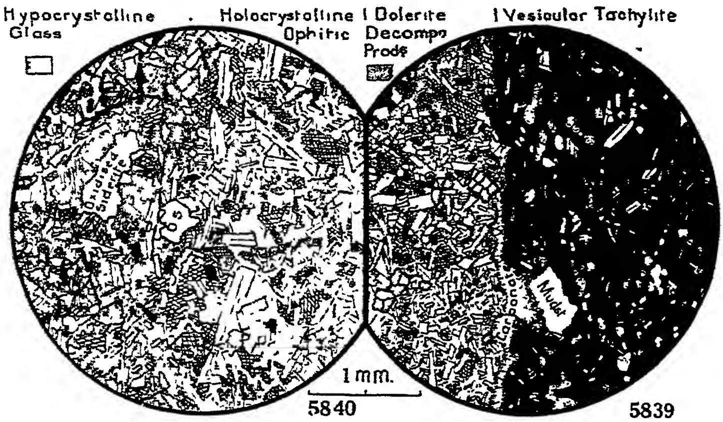
About fifteen feet higher in the sheet (5829) the grainsize is a little larger, the ophitic structure more pronounced and in place of most, if not all, the glass there is a finely granular rather strongly feldspathic but otherwise somewhat pilotaxitic groundmass around the vesicles or forming large, irregular patches up to 10 mm. across, containing besides granular augite, long ($< 0 \cdot 8$ mm.) thin augite prisms studded with magnetite, long rows of aggregated magnetite and platy ilmenite and numerous small patches of siderite. Olivine was very rarely present among the larger crystals, but pseudomorphs thereafter may be recognised. The larger grains of augite are sub-ophitic. The vesicles are filled with sphaerosiderite which rarely contains idiomorphic but indeterminable tabulae apparently of a zeolite. This rock lies at the base of a depression in the zone of holocrystalline augite dolerite. About the same horizon or possibly a little higher, though intersertal (5839) is without such micro-pilotaxitic material, but contains a little glass and rather more olivine than (5829). After it had consolidated and cooled it was invaded by thin (1–2 feet) dykes having tachylitic margins with more crystalline but still dominantly glassy central portions. (See Figs. 6 and 7.)

Rather higher, though still containing a trace of glass and a little olivine (5828) has developed irregular, finely granular, almost orthophyric or trachytoid patches 4–5 mm. across, consisting chiefly of squarish prisms or tabulae of labradorite-andesine with a minor amount of pyroxene and iron ores. The larger pyroxene crystals are normal, not very calcic augite, and are associated with or zoned by subcalcic augite. The larger plagioclases are surprisingly calcic and zonal feldspar more sodic than An_{50} forms only very thin mantles about the calcic cores. The explanation of this basicity is not obvious.

Above this the rock (5852) is holocrystalline and free from olivine. Its grain-fabric shows but a trace of the ophitic texture. The plagioclase ($< 0 \cdot 8 \times 0 \cdot 4 \times 0 \cdot 3$ mm.) and augite ($0 \cdot 4 \times 0 \cdot 3$ mm.) are associated with plates of ilmenite ($< 1 \cdot 0 \times 0 \cdot 1$ mm.) and irregular patches ($< 3 \cdot 0$ mm.) of cryptographic material together with some siderite.

A curious mingling of different phases of dolerite occurs at a horizon near, possibly a little below, that of (5852). A more or less "blotchy" effect is seen where the mingling is intimate (5841–2), and a sharper separation in other cases (5840). (See Fig. 7.) The paler portion has the general composition of the rock with the orthophyric trachytic mesostasis, but is more coarsely granular, and consists of elongated plagioclase (An_{50}), sometimes almost phenocrystic, with marked ophitic development of the very subordinate augite and little or no olivine or glass. The darker portion contains long prisms of augite and a little olivine, with platy ilmenite and glass, abundant near the contact but almost lacking a few feet away from it where

the rock (5896) is a subophitic, holocrystalline and rich in ferriferous minerals. This constitutes the "cementing matrix" of the irregular "conglomeratic" layer of aggregated quartzose xenoliths in the middle of the tidal platform which will be described in Section C of this paper. It would seem as if rather basic dolerite magma containing abundant xenoliths had been injected into and ramified within the Tawhiroko sheet just after it had completed gravitative differentiation and consolidation, but while it was still too hot to allow the formation of a tachylitic selvedge, though not hot enough to prevent the consolidation of some residual glass therein (cf. Walker, 1940, p. 1086–7). The rapidity of injection from the magma may account for the absence of hypersthene from the dolerite surrounding the xenoliths (5838, 5896), though some has been formed in the little veinlets injected into the xenoliths, where there has been greater opportunity for solution-reaction (cf. Lacroix, 1893, p. 34; Harker, 1904, p. 353). The injection of this xenolith-charged doleritic magma was so irregular that its varying spatial relations to the several gravitationally differentiated phases of the Tawhiroko sheet could not be fully determined, and it is not clear whether (5838) is portion of this later mass.



7. Welded (5840) and sharp (5839) contacts between coarse-grained dolerites and later intrusions in the Tawhiroko Sheet.

In the middle of the tidal platform (5827), which has no trace of olivine or of glass, contains interstitial alkali feldspars (anorthoclase ? and sodic andesine) in cryptographic or radial intergrowths between tabulae of calcic andesine and subcalcic augite. The last occurs in long magnetite-studded prisms or in ophitic intergrowth with plagioclase. Similar to this are (5855, –4, 3, –1) occurring above the tidal platform. They differ from (5827) chiefly in the occasional trachytoid texture of the interstitial material, and the increasing content of augite and calcic nature of the plagioclase towards the top of the sheet. Iron ores seem to have a slight maximum within this cryptographic zone, the higher members of which (5854–1) contained large crystals of calcic labradorite and rare small grains of olivine which sank but a short distance out of the upper marginal portion

of the sheet. Only in 5851 are there a few grains of quartz large enough for examination in convergent light.

The highest dolerite in Tawhiroko Hill (5856) is 72 feet above the tidal platform, about 10 feet above 5851, and was probably about 15 feet below the upper tachylitic margin of the sheet. In accordance with this, its plagioclase crystals are smaller and more calcic than those in 5851, the augite smaller, more calcic, and more abundant. The rock is slightly vesicular, and contains glassy and "micro-basaltic" interstitial material. There was very little if any olivine present.

Though the grain-size of the rock shows the normal increase from the margins towards the interior, uncertainty as to the precise thickness of the intrusive sheet, and the exact horizon therein of the specimens described prevents any quantitative study of the variation in grain-size (cf. Alling, 1936, pp. 321–327).

Breaking the cryptocrystalline zone is a coarsely granular, probably lensoid mass of pegmatoid dolerite, grading imperceptibly outward into the less coarse to medium-grained enclosing rocks. The least weathered specimen (sp. gr. = 2·75) contains much deuteric siderite which forms powdery haematite on weathering, leaving a porous rock (sp. gr. = 2·66) a sample of which was analysed (5750, Anal. 5, in Table VI). Assuming the pyroxene has a composition approaching that determined optically the calculated mineral composition would be—Quartz and chalcedony (in part deuteric) 13·5%, feldspar (Or_{13} Ab_{58} An_{29}) 63·7%, augite (Wo_{20} En_{52} Fs_{18}*) 7.7%, apatite 1·1%, ilmenite 5·7%, haematite replacing siderite 8·3%. Omitting the last mineral, the calculated sp. g. of the rock is 2.72. The illustration (Fig. 6) is that of a field containing rather more than the average proportion of coloured constituents. The larger feldspar crystals are zoned andesine, but there is approximately 20% of trachytoid, micropegmatoid or cryptographic matrix in irregular ovoid or interstitial patches consisting of lathy andesine-oligoclase and anorthoclase (?) with R.I. respectively equal to or less than that of Canada balsam. Most of the silica occurs in indeterminably fine quartz-feldspar intergrowths and as chalcedony in this matrix, but some (surprisingly few) clear grains (<0·3 mm.) of quartz may be seen. A little microlitic pyroxene and magnetite occurs with this felsitic matrix, which may surround vesicles filled with partially oxidised sphaerosiderite, and subordinate chlorite, quartz, chalcedony and opal. The composition of the pyroxene is transitional between normal and subcalcic. It forms relatively narrow, sometimes arcuate prisms up to 5 mm. long, though usually subophitic and zoned. The reason for such curvature is not apparent, though the feature has been noticed by several petrographers. Thus Bowen (1910) found it in Late Pre-Cambrian dolerite in Canada, Teall (1884) and Tomkieff (1929) in the Late Palaeozoic Whin Sill, Phillips (1899), Emerson (1905) and Shannon (1924) in the Triassic Palisadan dolerite sills of Eastern U.S.A., and Browne (1923) in Tasmanian and Antarctic dolerites. When present, it is nearly always associated with coarsely

* Probably the addition of a little of the normative anorthite and iron ore to the pyroxene would result in a closer approach to its modal composition.

granular, probably or certainly pegmatoid phases of the dolerite, a rather exceptional case being that described by Emerson in which the pyroxenes have assumed a curiously " plumose " type of spherulitic structure, and occur in a coarse-grained, but irregular narrow band near the margin of a main intrusion. In one case only there is a suggestion of a shearing movement in the consolidating rock; usually there is no evidence of this. Tomkieff's (*op. cit.* pp. 116–8) conclusion concerning similar but more sharply bounded coarse-grained dolerite in the Whin Sill, namely, that it was " possibly the result of ' wet ' differentiation formed in the intercrustal basin, caught up in the ascending magma and stretched out in the form of lozenge-shaped tabular bodies parallel to the walls of the injection chamber " is not applicable to this rock-mass, which seems to have formed by differentiation in *situ*. (See Shannon, 1924, p. 39, as quoted below p. 111, and Phemister, 1928, pp. 162–170).

In general, the vesiculation and abundance of deuteric minerals throughout this sheet indicates the abundance of fluxing volatile materials in the invading magma, and the consequent facilitation of its gravitative differentiation to a greater extent than occurs in the much thicker intrusive sheets of the Palisades (Walker, 1941), the Karroo (Walker, 1940, etc.), Tasmania (Edwards, 1942) or (so far as is known) Antarctica (e.g., Benson, 1916).* The need of fluxing to promote gravitative differentiation in sills was stressed by Harker (1916, p. 555), who noted that " clear instances of gravitative differentiation in sills and laccolites . . . are all in rocks which must represent very unusually fluid magmas such as the analcime-bearing intrusions of Permian Age in Scotland," and, we may add, the richly zeolitic theralitic intrusion at Waihola (Benson, 1942). The bulk of the water in the Tawhiroko, Main Moeraki and Mt. Charles intrusive sheets was probably magmatic, but this might have been supplemented by water derived from the plastic sediments which they invaded (cf. Leitmeier, 1909; Daly, 1917, p. 445, 1933, pp. 307–11; Shannon, 1924, p. 39), a view which Grout (1928, pp. 567–70) § opposed, though Day and Allen's (1925, pp. 76–84) application of Morey's (1922) experimental study of the absorption of water into silicate melts at low (even atmospheric) pressures of " meteoric water acquired in the usual way through contact with water-bearing strata or reaching the volcanic hearth under a head determined by the elevation of the crater basin," to the explanation of the effect of downward percolating snow-water in stimulating the eruptive activity at Lassen Peak, supports this view. The general course of the formation of these Otago Sills has, however, much in common with that of the large Palisade Sill (Walker, 1940, p. 1101). Thus:—

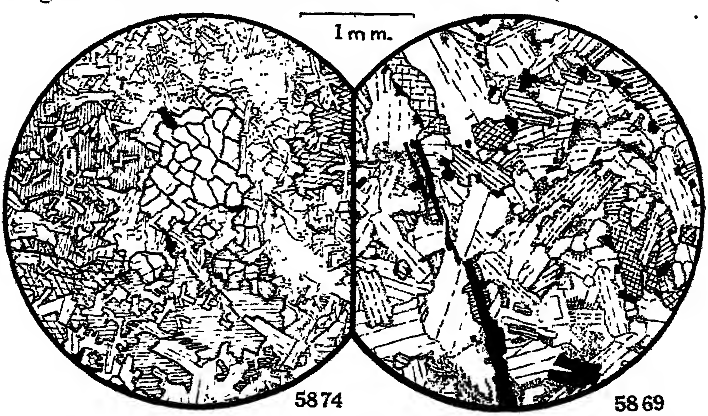
1. " The main differentiation was effected by the sinking of early-formed olivine followed at a later stage by pyroxene." The

* We may contrast these products of magmas not rich in fugitive constituents with the more deuterically altered and gravitationally differentiated diabase sill at Bridgehead, Ontario, which presents interesting analogies and contrasts with the N.E. Otago Sheets (Emmons, 1927, pp. 73–82); see also Phemister (1928, pp. 162–170, 185).

§ But see Grout (1932, pp. 212–3).

larger olivine crystals accumulated above the chilled base, a few of the smaller were retained by the stiffening melt near the upper margin.

2. "Although the sinking of the two minerals probably overlapped, crystalisation of olivine ceased at an early stage, when the magma was still fluid, whereas pyroxene continued to form and to sink until brought to rest by the increasing viscosity of the magma and by crystal interference."
3. " There was no appreciable sinking of iron ore."
4. " Interstitial alkaline feldspars are found in the upper portion of the sheet with micropegmatite and free quartz in its higher parts," but there is no evidence of albitisation or formation of albitic veinlets such as occur in the Palisade Sill.
5. The later stages of crystallisation were followed by pronounced hydrothermal activity resulting in formation of chlorophaeite and chloritic minerals with chalcedony chiefly at the expense of residual glass, bowlingite, quartz, chalcedony, and ferruginous and calcic carbonates, more or less in the above order.
6. Though the thickness of this sheet is so much less than that of the Palisade Sill or the Tasmanian sills (above 1000 feet) the range of average grain size of the plagioclase is but little different from that throughout the Palisade Sill and the lower 700 ft. of the Tasmanian Mt. Wellington Sill. Probably this resulted from a greater content of water in the magma, which also facilitated the gravitational differentiation.



8. Olivine dolerite (5874) near the base, and quartz dolerite (5869) 200 feet above the base of the Main Moeraki Sheet.

(e) THE MAIN MOERAKI DOLERITE SHEET.

The obscuring drift on hill-slopes prevents a detailed tracing of the differentiation-sequence in this sheet, though it may later be accomplished by a study of the high cliff half a mile north-west of the lighthouse, the base of which consists of olivine dolerite and the top of quartz dolerite. (See Benson, 1943, Fig. 8.) The two end-members of the series are, however, widespread. Olivine dolerite occurs always near the base of the intrusive sheet as at Tawitiatiauka (5860) and a quarter of a mile west thereof (5790) by the shore

near the Moeraki village, on the northern flanks of Trig E (5884), capping low hills half a mile east thereof (5895, 5874), off the shore by Matiaha Head (5886), and again immediately west (5887) of the lighthouse and half a mile north-west thereof (5888). On the other hand, the upper portion of the plateau extending north from the lighthouse (5879, –78, –97) and the tops of the higher hills near Trig E (5889, –90, –91), all 100–200 feet above the base of the sheet, consist of quartz dolerite, which dips eastward towards Okahau Point.

Olivine dolerite (5860), which is probably the rock analysed by Seelye (Table VI, Anal. No. 2), was collected 10-15 feet above the basal content with porcellanitised mudstone. Though slightly over-saturated with silica, it is a sub-ophitic olivine dolerite.* The dominent mineral is labradorite (An_{65-55}) in tabulae rarely over 1 mm. long. Augite (see Table III) is rarely half as large, the partially bowlingitised olivine crystals (Fa_{14-30}) may be up to 1·5 mm. long. Platy ilmenite and a little glass are also present. Other olivine dolerites from near the base of the sheet differ in minor details:—(5790) though of rather small grain-size has less glass; (5884–86), perhaps a litle further from the base, have no glass, but a little trachytoid mesotasis; (5886) some magnetite; (5884) less olivine and a rather coarser grain-size; (5874, 5895) about 30 feet above the base are very ophitic (Fig. 8), the individual pyroxene crystals sometimes extending over 3 mm. The small amount of partially decomposed glass in these rocks contains apatite needles and rare feldspar microlites. Near the lighthouse dolerites (5887–8) adjacent to porcellanite at the base of the sheet have been rendered friable by the almost complete replacement of pyroxene and olivine by dark green chlorite and bowlingite.

Differing from these is (5835) a porphyritic tholeiitic olivine dolerite (cf. 5834 in Fig. 6) occurring on the east coast near the lighthouse, adjacent to large included masses of sediment to the chilling effects of which it owes its texture. It contains phenocrysts of olivine and pyroxene, small interstitial patches of finely granular feldspathic microbasalt, and glass, the last chiefly around the vesicles. Its specially interesting feature is the presence of a small minutely-granular aggregate of bytownite and spinel, resulting from the fusion and recrystallisation of a marly xenolith, as will be described in Section C of this paper.

Quartz-bearing Dolerites (5869; see Fig. 8), 5878–79, –89, –90, –91, and –97) are typical and closely similar, A more coarsely granular rock (5880) occurs on the shore near Okahau Point. The pyroxene (see Table III) forms short or long prismoid or sub-ophitic to typically ophitic plates, the last of which may be over 3 mm. across. Slight chloritisation of the pyroxene is sometimes seen, especially in (5891). Sometimes (5878) the pyroxene occurs graphically intergrown with plagioclase especially in the terminal portions of the smaller tabulae, or occurring in still finer division in the alkaline feldspars extending sub-radially from the margins of

* "The norm always tends to make the rock appear more acid than it really is, and therefore a small amount of normative quartz, up to 2% say" (4.32% in Analysis No. 2) "is compatible with the normal basaltic composition" (Phemister, 1934, p. 42).

such tabulae into the interstitial micrographic material. Hornblende occurs sparsely in (5891). Its features have already been described (p. 84). Ilmenite forms plates up to 3 mm. long, and rarely seems moulded on feldspar (5878), the reverse being the more common relation. Leucoxination is well displayed in (5891). Rarely (5879) haematitic derivatives of deuteric carbonates are associated with talc in what seems to be pseudomorphs of small olivine grains. The plagioclase tabulae 2–3 mm. long, or 5 mm. in (5880) which resembles (5750) of the Tawhiroko Sheet (see Fig. 6), are strongly zoned with a core of labradorite (An_{60}) or basic andesine and marginal zones sometimes as sodic as An_{25}. They contain needles of apatite in general more abundant than in the Tawhiroko Sheet. The interstitial material varies even within a single rock. It may be a trachytoid aggregate of relatively large ($<$ 0·5 mm.) microlites of oligoclase and anorthoclase or minutely fibrous intergrowths extending radially or in curved plumose tufts (5897) from the corners of the tabulae, and both of these structures may be associated with a little bleached residual glass (5879, –91) which in the latter rock has been partly replaced by opal. Commonly it frays out through crypto- or micrographic intergrowths into crystals of quartz which may terminate idiomorphically against ferruginous carbonates. Apatite needles are very abundant in such intergrowths. The varied features and sequence of the silica minerals, quartz and chalcedony, in these rocks, and their significance have been already discussed. (See p. 87.)

In the coarsely granular dolerite in the cliffs above Matiaha Head (5872) the residual interstitial magma did not consolidate with the formation of micropegmatite, but as glass now probably hydrated with R. I. = 1·497, but varying between 1·489 and 1·500, with or without the usual opaque trichites and margarites or microlites of oligoclase, augite, ilmenite and magnetite. The pyroxene in this rock was strongly differentiated during crystallisation and shows the only instance of "reversed zoning," observed among the rocks described herein. (See Table III.)

A relatively small and a very large lenticular aggregate of quartzose xenoliths in this sheet occur respectively by the shore near Matiaha Head and the hilltop 700 yards W.S.W. thereof.

The very large mudstone xenoliths in this sheet are surrounded by a narrow film of olivine-bearing tachylite (5833, 5881) grading through rather finely granular vesicular tholeiite (5825) into the nearby (5885) and perfectly normal coarse-grained dolerite (5885). Here and there veins or irregular segregations of more or less calcitic chalcedony traverse the rocks of this sheet.

(f) OTHER MID-TERTIARY BASALTS, THOLEIITES AND DOLERITES.

These are widespread, but as most of them closely resemble rocks in the Moeraki Peninsula detailed descriptions are rarely necessary. Porphrytic olivine basalt with a pilotaxitic to fluidal holocrystalline fine to medium-grained ground-mass is not known in this peninsula. It forms the sheet (5752) in Lookout Bluff (Loc. 84, Trig. D, Otepopo S.D.), and the volcanic plug (5866) half a mile south of Totara railway station (Loc. 98A). It usually contains phenocrysts of olivine only. A little stilbite (?) occurs in 5752.

Porphyritic basalt (5721) with phenocrysts of olivine, augite, singly or in ophitic or glomeroporphyritic groups of labradorite, set in a ground-mass like that of (5734), invaded both the Waiarekan tuff and the Ototaran limestone at Loc. 98, a mile N.E. of Maheno. (See Benson, 1943, Fig. 2.)

Medium-grained *olivine dolerites* with a little intersertal glass are represented by the rock (5724) forming Round Hill (Loc. 100 = Trig. K, Oamaru S.D.), and (5719) the lower portion of the igneous cap on Kauroo Hill (Loc. 100, Kauroo S.D.). (See Benson, 1942a, p. 114.) These are closely similar to rocks in the lower part of the Tawhiroko Sheet, but contain less glass than otherwise similar material in the flow west of Tokarahi (5725) and in the centre of the large pillow (5763) in Awamoa Creek.

Very coarsely granular intersertal olivine dolerite forms the top of South Peak (Loc. 82) (5722) and North Peak (Loc. 81) (5716). Both are beautifully ophitic and in the latter the mesotasis is largely devitrified with formation of skeletal extensions of the major feldspar tabulae and other feldspar microlites. The olivine (Fa_{15}) is unzoned as is also the augite (2 V = 50°, 51°) and the plagioclase mostly basic andesine (An_{52-42}). A similar rock (6785) occurs also at Enfield (Loc. 105 = Teaneraki), but has been very greatly affected by carbonation.

Coarsely granular, more or less ophitic holocrystalline dolerites with pseudomorphs after olivine were collected by Marshall (?) from various unspecified localities near Mt. Charles (Loc. 86). The most olivinic (6787) is least coarsely crystalline and without micropegmatite, less olivine occurred in the more coarsely granular rocks (6788, 6791) in which a little micropegmatite appears, less again where the intergrowth becomes abundant and radiating quartz with undulose extinction is enclosed within deuteric carbonates (6790). The usually unzoned augite in this rock has 2 V = 61° ± 3°, 56°, 54°, 52°. Its other optical properties and inferred composition are shown in Table III and Fig. 4 (I). It is not clear that these strongly calcic pyroxenes formed under plutonic conditions prior to magma injection. The plagioclase when completely enclosed in augite is An_{70}, but where exposed varies from An_{58} to An_{40}, the last being the composition of a small excresence from a tabula projecting into quartz. The only localised specimen (5727) came from well above the base of the sheet in the cliffs adjacent to the railway, 200 yards north of the Waianakarua Bridge (Loc. 85). It contained still less olivine and less calcic unzoned pyroxene (2 V = 54°–45°). The abundant and not very finely granular micropegmatite in this rock is associated with more and larger (< 1·0 mm.) grains of optically uniform quartz than in any other dolerite described in this paper. Finally, it is to be noted that Hutton (1887, p. 428) found no trace of olivine, but some "enstatite" (hypersthene?) in rocks obtained by him from Mt. Charles. It remains to be seen whether such hypersthene is here normally magmatic or the result of local solution of quartzose xenoliths by the basic magma. The range of petrographic features displayed in this sheet suggests that it also will be found to be gravitationally differentiated.

Anorthoclase-bearing porphyritic olivine basalt (5734), containing a little indeterminable zeolite, invades the Waiarekan tuff near Maheno (Loc. 97, Trig. S, Otepopo D.) and caps Government Hill (5741) (Loc. 87, Trig. O, Otepopo S.D.) and probably also the adjacent Little Table Hill. The analyses of these rocks (Table VII, Anal. 3–4) show a greater amount of potash than those of the Moeraki Sheet, and this is expressed mineralogically by the development of anorthoclase tabulae in small amount, usually associated with sparse, minute flakes of (partly deuteric) red-brown biotite.

Analcite olivine dolerite of medium grain-size (5749) occurs a mile and a-half west of Maheno (Loc. 96) and forms part of the same rather alkaline sheet as the above. The olivine (< 0·9 mm.) is fresh and slightly zoned, the plagioclase (< 0·5 mm.) is basic andesine (An_{47}), and the granular augites are up to 0·5 mm. in diameter. Ilmenite plates, usually idiomorphic but rarely moulded on olivine, may be 1·2 mm. long. Magnetite is also present. Anorthoclase in small amount forms tabulae (< 0·2 mm.), or is moulded between the plagioclase tabulae. Biotite flakes, rarely 0·2 mm. in diameter, but more usually < 0·05 mm. and probably deuteric, are associated with chlorite. Analcite forms rare patches (< 0·4 mm.) or veinlets replacing feldspar, and there are a few relatively large (0·6 x 0·03 mm.) prisms of apatite as well as minute needles. The rock differs from crinanite in being less basic, having normal rather than titaniferous augite, a non-ophitic texture and a much greater amount of potassic feldspar.

Coarse-grained *basic analcite syenite or melasyenite* (5865) occurs by the Waimotu railway station (Loc. 97A) a mile south of the last rock, and forms probably a pegmatoid segregation in the same intrusive sheet. The largest crystals (5·0 x 0·2 or 3·0 x 2·0 mm.) are of basic oligoclase, but these are subordinate to the anorthoclase. The oligoclase has been attacked by deuteric alkaline solution with the development of checkered patches of albite (?) and analcite. The anorthoclase, having the characteristic optic properties already noted (see p. 12) forms idiomorphic zoned tabulae (2 x 1·5 mm.), and is usually transparent in the marginal portions though it may be turbid within. Both feldspars contain abundant needles of apatite. Biotite plates (1·0 mm. long) were common and less so are thin, faintly purplish prisms of augite ($2V = 57°$) which may be 1·6 mm. long but usually much less. Sometimes short, pale, weakly pleochroic prisms occur with a greenish sodic shell. Both the augite and biotite have been more or less converted to dark green chlorite. Aggregates of octahedral magnetite (< 0·4 mm.) and scattered plates of ilmenite (< 1·0 mm.) are abundant, often growing out from the augite or biotite in branch-like fashion. The interstices are filled with straight or arcuate laths of anorthoclase in a chloritic matrix. Analcite in idiomorphic (?) or rectilinearly bounded interstitial masses (< 1·5 mm.) is common, and its late development is shown by its being moulded on the anorthoclase microlites in these areas. It contains abundant minute liquid inclusions, but is almost free from inclusions of minerals. Natrolite (?) enclosing carbonates is locally moulded on the corroded margin of analcite. This rock, so different from any Late Tertiary product, is the most alkaline derivative of the Mid-Tertiary basic rocks.

TABLE VI.—ROCK ANALYSES.

Chemical Composition and Petrological Affinities of Mid- and Late Tertiary Basic Igneous Rocks of Otago.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	52.92	50.42	49.44	47.39	55.94	52.73	52.61	50.52	49.3	48.8	52.10	50	45	46.16
Al_2O_3	16.35	14.09	14.46	13.35	13.61	15.14	13.93	13.76	12.2	13.6	16.37	13	15	15.32
Fe_2O_3	2.05	3.57	1.95	1.95	7.83	2.40	3.03	3.87	4.7	5.1	3.27	13	13	3.50
FeO	7.62	6.30	8.75	9.78	3.36	7.57	7.39	8.50	9.2	8.5	4.99			9.67
MgO	5.33	6.59	7.89	10.01	1.71	6.70	5.60	5.42	5.5	5.3	5.76	5	8	7.25
CaO	8.32	7.97	8.10	8.80	4.86	8.17	9.62	9.09	9.4	8.4	8.20	10	9	9.58
Na_2O	3.36	3.11	3.39	3.02	4.03	3.34	2.42	2.42	2.1	2.6	3.03	2.8	2.5	3.74
K_2O	0.96	0.66	1.21	1.20	1.33	1.01	1.22	0.96	1.1	0.8	1.76	1.2	0.5	1.34
H_2O+	1.26	1.54	1.48	1.48	1.42	—	1.05	1.51	2.7	3.2	2.56	—	—	—
H_2O-	0.57	3.40	0.78	0.60	2.78	—	1.00	0.76						
CO_2	nil	tr.	nf.	tr.	tr.	—	0.45	0.58	—	—	1.20	—	—	—
TiO_2	0.93	1.58	1.88	1.94	2.81	2.21	1.21	2.39	3.1	2.5	0.67	—	—	2.45
P_2O_5	0.33	0.34	0.46	0.40	0.43	0.39	0.21	0.26	0.4	0.4	0.21	—	—	0.65
ZrO_2	nf.	nf.	nf.	nf.	nf.	—	—	—	—	—	—	—	—	—
S	0.06	0.07	0.05	0.03	0.05	0.06	0.09	—	—	—	0.08	—	—	0.04
MnO	0.12	0.12	0.14	0.15	0.06	0.13	0.23	0.16	0.2	—	—	—	—	0.21
BaO	0.03	0.02	0.03	0.02	0.04	0.03	0.03	—	—	—	—	—	—	0.11
SrO	0.01	0.09	0.04	0.03	0.02	0.04	—	—	—	—	—	—	—	0.04
Cr_2O_3	0.04	0.04	0.04	0.06	nf.	0.04	—	—	—	—	—	—	—	0.03
V_2O_3	0.02	0.03	0.02	0.03	0.02	0.02	0.06	—	—	—	—	—	—	0.01
NiO	0.02	0.03	0.02	0.03	nf.	0.02	—	—	—	—	—	—	—	0.02
Cl	Tr.	Tr.	nf.	nf.	0.04§	—	—	0.11*	0.2	0.8	—	—	—	—
Total	100.30	99.97	100.13	100.27	100.34	100.00	100.15	100.31	100.1	100.1	100.10	—	—	100.12
Sp.gr.	2.725	2.79	2.90	2.94										

§ Soluble in water. Probably dried sea spray: * Minor Constituents.

EXPLANATION OF TABLE VI.

LIST OF ANALYSES.

1. Tachylitic margin of pillow lava (5701), Boatman's Harbour, Oamaru. F. T. Seelye Anal.; R.I. 1.5772 + 0.0002 and sp. g. by C. O. Hutton.
2. Olivine dolerite (5860 ?); Tawitiatauka Point, Moeraki. F. T. Seelye Anal.; sp. g. measured on (5860). Analysed specimen not available.

3. Porphyritic olivine basalt (5734); Trig. S, Maheno S.D. F. T. Seelye Anal.
4. Porphyritic olivine basalt (5741); Government Hill, half-mile S.W. of Trig. O, Otepopo S.D. F. T. Seelye Anal.
5. Pegmatoid dolerite (5750); near centre of Tawhiroko Sheet. F. T. Seelye Anal. Fe_2O_3 chiefly derived from oxidised siderite.
6. Average of 4 parts each of 1 and 2, 2 parts each of 3 and 4, and 1 of 5 (with adjustment for its excess of Fe_2O_3). Considered as the average Mid-Tertiary magma of N.E. Otago.
7. Average composition of 19 English tholeiites listed by Holmes and Harwood (1929).
8. Average composition of 6 English quartz-dolerites of the Whin Sill type listed by Holmes and Harwood (1928).
9. Average of 6 Scottish tholeiites (Walker, 1935).
10. Average of 6 Scottish quartz dolerites (Walker, 1935).
11. Average of five German tholeiites listed by Rosenbusch (1910) and Troger (1935).
12. General composition of the tholeiitic magma type.
13. General composition of the olivine basalt magma type. Nos. 12 and 13 both after Kennedy (1931, 1933).
14. Average composition of Late Tertiary basaltic igneous rocks in regions peripheral to the Dunedin District (Benson, 1942).

(g) THE CHEMICAL COMPOSITION AND PETROLOGICAL AFFINITIES OF THE MID- AND LATE TERTIARY BASIC IGNEOUS ROCKS OF OTAGO.

It will be seen that the average Mid-Tertiary basic magma in North-Eastern Otago (No. 6) contrasts sharply with the Late Tertiary basaltic magma of Eastern Otago (No. 14), which in turn differs from Kennedy's (1931, 1933) olivine basalt magma type (No. 13) chiefly in its greater content of alkalies. On the other hand the average Otago Mid-Tertiary basic magma resembles rather closely the average English and Scottish quartz dolerites (Nos. 8 and 10), the average German tholeiites (No. 11) and still more closely the average of these three groups. It differs from all of them, except the German tholeiites, chiefly in its greater content of soda, a distinction which would still remain if the Otago average were calculated without reference to the anorthoclase-bearing basalts (Nos. 3 and 4) which yield a syenitic pegmatoid rather than the micrographic pegmatoid as in the remaining dolerites and in typical tholeiite-dolerite associations (Kennedy, 1933, p. 244). If comparison be made with the average composition of undifferentiated marginal portions of the Palisade Sill (Walker, 1940, p. 1080), and with that similarly of the Tasmanian dolerites (Edwards, 1942, p. 465) and the averaged composition of Western Australian tholeiites (Edwards, 1938, p. 7) also of Spitzbergen (Tyrrell and Sandford, 1933, p. 312) and Antarctic dolerites (Browne, 1923, p. 253), the same essential resemblance but with greater alkalinity in the Otago rocks is again clear. The Otago Mid-Tertiary and Late Tertiary basaltic magmas may therefore be taken to represent in some measure respectively rather alkaline facies of the tholeiitic and olivine basalt magma types of Kennedy (*opp. cit.*). The relationships as far as they concern the Mid-Tertiary and tholeiitic rocks, are made clearer by a comparison of average normative compositions as given in Table VII, and of normative and modal developments of pyroxenes given in Table VIII.

TABLE VII.

Normative Compositions of Quartz Dolerites, Tholeiites, Plateau Basalts and Non-alkaline Pacific Basalts.

Note	Rock Series	No. of Anal.	Feldspar Or	Ab	An	%	Pyroxene Wo	En	Fs	%	Qtz. %	Ores %	Apatite %
1	Otago Dolerite and Tholeiites	5	11	51	38	58.6	18	60	22	31.2	1.4	7.8	1.0
2	Antarctic Dolerites	4	10	26	64	52.1	19	56	25	40.9	2.8	2.3	Tr.
3	Tasmanian Dolerites	6	10	27	63	54.0	23	47	30	42.2	3.9	2.0	Tr.
4	Karroo, South Africa, Dolerites	15	10	41	49	52.7	24	42	34	42.2	1.1	3.4	0.3
5	Palisadan Dolerites, U.S.A.	20	10	37	53	53.9	16	55	29	40.7	1.0	5.0	0.3
6	Watchung Basalt, Eastern U.S.A.	8	9	40	42	51.6	22	50	28	35.7	3.6	8.8	0.3
7	British Quartz Dolerites	12	11	43	46	51.5	25	51	24	30.1	6.1	11.6	0.7
8	British Tholeiites	25	16	41	43	51.4	29	49	22	33.6	5.6	8.7	0.7
9	German Tholeiites	5	16	42	42	63.8	21	62	17	25.8	4.0	7.2	0.4
10	Western Australian Tholeiites	3	6	47	47	52.7	30	45	25	37.0	3.1	6.6	Tr.
11	Spitzbergen Quartz Dolerites	4	12	34	52	51.2	31	46	23	34.7	3.3	10.5	0.3
12 13	Plateau Basalts, Deccan and Oregon	22	10	46	44	50.9	25	43	32	35.9	3.9	8.8	1.0
	Pacific Basalts	42	7	47	46	50.2	25	54	21	39.2	0.4	9.5	0.7

NOTES TO TABLE VII.

1. Analyses by F. T. Seelye. Average in Column 6, Table VI.
2. Average of analyses by Prior (1907). Benson (1916), Osborne and Graham (in Browne, 1923).
3. Average of analyses of undifferentiated marginal dolerite made by Edwards (1942).
4. Average of modern analyses by Herdsman and others cited in various papers, chiefly by Walker.
5. Average of 12 analyses from the Palisade Sill, and others from adjacent parts of New Jersey, Connecticutt and Virginia, chiefly by Gage and Gonyer. (See *inter alia* Lewis, 1907; Walker, 1940).
6. Analyses chiefly by Gage of the effusive products of the Palisadan magma. (See Lewis, 1907).

7. Average composition of six English and six Scottish dolerites selected by Walker. Analyses by Harwood and others. (See Holmes and Harwood, 1928; Walker, 1935.) An earlier average by Tyrrell and Sandford (1933) including 24 analyses of the Whin Sill dolerite gives $Or_{12}Ab_{38}An_{50}$ 54.3%, $Wo_{22}En_{50}Fs_{28}$ 38.0%, quartz 7.3%, iron ores 9.9%, apatite 0.7%.
8. Average composition of 19 English and 6 Scottish tholeiites by various analysts, chiefly Harwood and Herdsman. (See Holmes and Harwood, 1929; Walker, 1935.)
9. Average of five analyses of German tholeiites listed by Rosenbusch (1910), Rosenbusch-Osann (1923), and Tröger (1935).
10. Average of three analyses by Edwards (1938).
11. Average of four analyses by Herdsman, Harwood and others selected out of the eight cited by Tyrrell and Sandford (1933).
12. Average of 16 analyses of Deccan basalt and six of Oregon basalt, chiefly by Washington. (See Washington, 1922; Tyrrell and Sandford, 1933.)
13. Average of analyses, chiefly by Washington and Keyes, omitting oligoclase basalts and other more alkaline types. (See Washington, 1923; Washington and Keyes, 1926, 1928; and Lacroix, 1927.)

TABLE VIII.
Comparison Between Normative and Modal Pyroxene in Representative Rock Series.

Notes	Rock Series	No. of Anal. in Av.	Normative Pyroxene			Modal Pyroxenes			
			Wo	En	Fs	Augite 2 V > 40°	Subcalcic Augite	Pigeonite 2 V < 30°	Ortho-Pyroxene
X	Japanese Andesite	42	8	58	24	Abun.	Subord.	Rare	Abun.
Y	Japanese Basalt	40	16	48	30	Domnt. ?	Subord.	Subord.	Subord.
1	Otago Dolerite, etc.	5	18	60	22	Domnt. ?	Subord.	Absent	Absent ?
2	Antarctic Dolerite	4	19	56	25	Abun.	Subord.	Abun.	Subord.
3	Tasmanian Dolerite	6	23	47	30	Abun.	Abun.	Subord.	Abun.
4	Karroo Dolerite	11	21	43	36	Abun.	Abun.	Abun.	Subord.
5	Palisadan Dolerite	4	21	46	33	Abun.	Abun.	Abun.	Abun.
6	Watchung Basalt	8	22	50	28	Subord.	Abun.	Absent ?	Absent ?
7	British Dolerite	12	25	51	24	Dominant		Rare ?	Rare
8	British Tholeiite	25	29	49	22	See Below			
9	German Tholeiite	5	16	42	42	Dominant		Not Reported	
10	Western Australian Tholeiite	3	30	45	25	Subord. ?	Subord. ?	Domnt. ?	Absent
11	Spitzbergen Dolerite	4	31	46	23	Abun.	Abun. ?	Subord.	Absent
12	Plateau Basalt	22	25	43	32	Abun.	Domnt. ?	Rare	Absent
13	Pacific Basalt	42	24	54	21	Abun.	Subord. ?	Rare	Rare

NOTES TO TABLE VIII.

X and Y. Mineralogical data from Kuno (1935) and Tsuya (1937). Optical determinations of clinopyroxene compositions plotted on Figure 9 herewith. The non-alkaline types of basalt are alone considered. Analyses chiefly by Tanaka.

1. Data as given above.
2. Mineralogical data from Prior (1907), Benson (1910) and Browne (1923).
3. Mineralogical data from Edwards (1942) and papers cited by him.
4. Normative composition kindly supplied by Professor Walker based on analyses (some unpublished) of undifferentiated marginal phases. Mineralogical data from Walker and Poldervaart (1941, 1942).
5. Normative composition of pyroxene communicated by Professor Walker and calculated from selected analyses of undifferentiated marginal phases. Mineralogical data chiefly after Walker (1940).
6. Mineralogical data after Lewis (1907) and Fenner (1910).
7. Mineralogical data after Holmes (1928), Tomkieff (1929), and Walker (1935). "Pigeonite is most common in rocks poor in hypersthene" (Holmes). "Clinopyroxene abundant: orthopyroxene common in coarse varieties but subordinate to clinopyroxene; pigeonite less common" (Walker, priv. com.).
8. Mineralogical data after Holmes (1929) and Walker (1935). "Orthopyroxene or pigeonite completely serpentinised. No determinations of 2 V less than 45°" (Walker, priv. com.).
9. Mineralogical data from Rosenbusch (1908), Rosenbusch-Osann (1923), and Tröger (1935).
10. Mineralogical data after Edwards (1938). Pigeonite (2 V = 0°–5°) sometimes abundantly present, together with clinopyroxene with rather higher 2 V, in some instances about 45° (subcalcic augite?) or with "fairly large 2 V," probably diopsidic.
11. Mineralogical data from Tyrrell and Sandford (1933).
12. Mineralogical data from Washington (1922), and Fermor (1925).
13. Mineralogical data chiefly from Barth (1931c).

The first comment to be made on these two tables is that while the normative compositions of pyroxenes have been calculated in terms of the three standard molecules, they cannot represent adequately the average modal composition. The presence of olivine in many of the rock-series, notably X, Y, 1, 4, 7, 10 and 12, would make the normative pyroxene usually appear less ferruginous than the average modal composition, since, except in the case of the Japanese rocks, we are dealing with normal, not unusually ferruginous rocks.* The same would result from the presence of quartz, tridymite and or cristobalite, e.g., in X and Y and occasionally in 12, and from the presence of quartz and olivine together in rocks of several of the series of dolerites. Further, as Hess (1941, p. 587) indicates, the presence of Fe_2O_3 and TiO_2 in modal pyroxenes which appear as iron ores in the norms, has the same general effect. The presence of Al_2O_3 in the modal pyroxene would involve the entry into the latter of CaO normatively alloted to anorthite. Hence En is often higher, Wo and Fs lower in the normative than in the modal pyroxene.† The average modal pyroxene composition of the Otago clinopyroxene as optically determined, viz., Wo_{26} En_{52}

* In the latter it is possible for modal olivine to be richer in iron than the accompanying clinopyroxene. (For description, discussion and explanation of an instance of this, see Smith, 1941).

† The reverse relation seems to hold, however, in regard to the average normative and modal compositions of the pyroxene in the in part olivine-bearing Karroo dolerites. (See Fig. 9, p. 117.)

Fs_{22} when contrasted with the normative average Wo_{18} En_{60} Fs_{22} affords a partial example of this. It may further be added that comparison of the normative compositions of the Palisadan dolerites and their effusive equivalents, the Watchung basalts, gives an interesting example of the rule that the latter, while containing about the same amount of total alkalies are richer in soda and also in iron. These differences "probably indicate that the basalts represent the parent magma more closely than the dolerites, the latter having advanced a stage in differentiation" (Tyrrell, 1933, p. 311). On the other hand, the composition of the Oamaru tachylite (No. 1), except for its low content of TiO_2, resembles very closely the calculated average composition (No. 6) of the Mid-Tertiary basic magma from which it was derived.

Nevertheless the development of these Mid-Tertiary Otago igneous rocks is not precisely in accord with that specified by Kennedy (1931, 1933) as typical of tholeiitic rocks. Not only is there a greater development of olivine in the more basic members, but pyroxene phenocrysts (not, however, markedly titaniferous) are common in the perphyritic members, and the trend of pyroxene-differentiation is marked by almost constant content of En with Fs increasing at the expense of Wo as in the olivine basalts rather than by decreasing En as specified by Kennedy for tholeiitic rocks, and by the absence of true pigeonite. Moreover, the close association of rocks yielding analcitic anorthoclase syenite pegmatoid with those developing quartz granophyre pegmatoid shows that here rocks with features resembling those of derivatives of the olivine basalt magma-type are not as sharply separated from rocks with features held to be distinctive of the tholeiitic magma-type as Kennedy held to be always the case.

(h) THE ABSENCE OF PIGEONITE FROM THE DOLERITES OF NORTH-EASTERN OTAGO AND ITS EXPLANATION.

If the available analyses of these Mid-Tertiary igneous rocks of Otago, averaged in the proportions tentatively assumed, yield a sufficiently representative average bulk normative composition, it is noteworthy, in view of the occurrence of several phases of pyroxene in other rock-series containing more calcic average normative pyroxene (Palisade, Karroo, Tasmania), that there should occur in the Otago dolerites only the single phase of clinopyroxene ranging uninterruptedly from diopsidic to calcic and subcalcic augite, except for such rare occurrences of hypersthene as are (or perhaps may be) the product of reaction between the magma and its contained quartzose xenoliths. The extent and nature of the crystallisation of the magma prior to its eruption, and especially the rapidity of its subsequent consolidation, appear to be the main factors in determining this contrast in mineralogical rather than in chemical features.

In the Palisade and Tasmanian dolerites, orthopyroxene occurs as microphenocrysts in the chilled marginal phase, where it was the first femic mineral to form after olivine if the latter be present (cf. Walker, 1940, p. 1072; Benson, 1917, p. 33; Edwards, 1942, p. 587). In the basaltic contact phase of the Palisade sill it occurs " in minute

granules surrounding olivine, and is obviously a reaction-product." In that of the Karroo sills, and indeed in the Karroo dolerites in general, it occurs only in the absence of olivine, with which it again may have a reaction-relationship (Walker and Poldervaart, 1941, pp. 140, 143). In all three of these regions the magma was injected, usually in large volumes, into sub-aerially formed sandstones and mudstones sufficiently long after their deposition to allow such compaction as would have materially reduced the amount of their contained water.‡ The specific heats and diffusivities of the invaded sediments were thus relatively low, so that large intrusive masses cooled sufficiently slowly to allow the development of more or less stable equilibrium-phases of pyroxene through a prolonged series of inversions and reactions—e.g., olivine → bronzite → early pigeonite → augite → late pigeonite—carried to varying stages of completion, and the formation of exsolution lammellae in one or more of them (cf. Walker and Poldervaart, 1942, pp. 438–9).

Conditions were quite otherwise as regards the North-East Otago rocks. The marginal tachylites and consequently the invading magma carried crystals of plagioclase of usually some olivine, but little or no pyroxene, which, in the case investigated (5831), was normal augite ($2V = 54°–49°$). It was injected for the most part in comparatively small volumes into recently deposited and often still plastic marine sediments which were at the time below the sea.* They would have a high content of water, and consequently relatively high specific heat and diffusivity (Clark, 1942, p. 258). Cooling of the magma was therefore rapid, and would be hastened by the latent heat of vapourisation of water absorbed into the magma (cf. p. 98). As a result, though the magmas contained enough water to permit as coarse crystallisation as, and a greater degree of gravitational differentiation than that in the much thicker sills of less aqueous magma injected into the sediments enclosing the thick Palisade, Karroo and Tasmanian sills, consolidation was too rapid to permit the attainment of equilibrium by reactive partition between the several types of pyroxene, and the course of crystallisation, starting at an abnormally low temperature, passed relatively quickly and uninterruptedly from the formation of stable normal augite to that of outer zones or individual crystals of largely metastable subcalcic augite with increasing content of Fs, following the trend explained by Dr. Edwards in Appendix II hereto.

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‡ The decrease of pore-space was probably less marked in some Triassic sediments when invaded by the Triassic Palisadan magma (see Shannon, 1924, p. 39, quoted below) than it was in the Permian to Jurassic sediments when invaded by the Karroo and Tasmanian dolerite magma, or in the marine and continental Carboniferous to Jurassic sediments when invaded by the Cretaceous dolerite magma of Spitzbergen (Tyrrell and Sandford, 1933).

* Exceptions to this are afforded by the dolerites of North and South Peak (5716. 5722) which invade the Upper Cretaceous sandstone 500–1000 or more feet below the level into which the Mt. Charles and Moeraki Sheets were injected. They contain, however, only normal augite ($2V = 51°–50°$), and for various reasons do not afford a critical test of this explanatory hypothesis.

Shannon (1924, p. 39) has described an exceptional sill in shales of the Newark series belonging to the general Palisadan assemblage. "Shales are highly hydrated rocks, and the most conspicuous features of the shales adjacent to the intrusive, both at Goose Creek and elsewhere, is a loss of shaly structure and a compacting and hardening doubtless due to loss of water. A body of molten magma of diabasic composition, surrounded on all sides by hydrous shales, would certainly tend to increase its content of dissolved water by solution of the highly heated water of the adjacent shales. In sandstones there would be less necessity for the water to dissolve in the magma, since it would be more free to move outward from the heated zone. This may explain the greater frequency of the occurrence of differentiation and other aqueous effects in shales than in those in sandstones or relatively anhydrous rocks. . . . If the magma crystallises from the early cooled walls inward, there must be a concentric inward expulsion of water, which in the ideal case would result in centrally placed pegmatite. . . ." It is worthy of remark that the pyroxene in the pegmatoid of the Goose Creek sill (*op. cit.*, p. 11) is a uniform augite with "2 V medium", Wo_{31} En_{40} Fs_{29} by chemical analysis, and without a trace of exsolution lamellae or indication of the presence of pigeonite. On the other hand, the pegmatoid phases of the less aqueous Tasmanian and Spitzbergen dolerites contain both normal augite and pigeonite (Edwards, 1942, p. 479; Tyrrell and Sandford, 1933, p. 306). The contrast exhibited by British rocks between the varied development of pyroxene in quartz-dolerites and the usually (?) less diversified range in the more quickly chilled tholeiites (see Table VIII) may be noted, also the rarity or absence of orthopyroxenes in the plateau basalts, etc.

APPENDIX I.

AUGITE, SUBCALCIC AUGITE, PIGEONITE AND THE CLASSIFICATION OF NON-ALKALINE CLINOPYROXENES.

Discussions as to the rôle of pigeonite in basic igneous rocks have been confused by the wide diversity of significance attached to the term pigeonite by various authors. The history of its usage (in part displayed in Table IX) has been summarised by Fermor (1925), Barth (1931a) and Hess (1941), the last of whom has put forward a revised classification of the pyroxenes of normal mafic magmas, which has been interestingly discussed by Walker (1943). There has also been a diversity of usage of the term hypersthene-augite, and of opinion as to the existence in rock-magmas of partial immiscibility between "augite" and pigeonite (with 2 V less than 32°) as most workers have believed, or of complete immiscibility under all conditions of cooling, as Hess (1941, pp. 518–519, 588) holds in the case of clinopyroxenes containing En and Fs in such proportions as occur in normal basic igneous rocks. "In practically all of them," he remarks, "there is a gap in optic axial angle between 2 V = 30° and 2 V = 40° as Kuno (1936) observed." The present writer has attempted an independent checking of this generalisation (Table X) in which he has been greatly helped by Professor Walker, who kindly furnished unpublished details of optic axial angles of pyroxenes in Scottish dolerites, and those of

the Palisade sill, and with Dr. Poldervaart, a large number of angles measured by them for pyroxenes in the Karroo dolerites.

Moreover, Professor Walker has kindly provided the following additional details of measurements of 2 V made chiefly by the Mallard method with accuracy of only ± 4°.

Palisade Dolerite: 50° (1); 50°–45° (23); 45°–40° (14); 40°–35° (5); 35°–30° (3); 30°–20° (9); 20°–10° (7); 0° ± (10) with 28 measurements of orthopyroxene about as abundant as clinopyroxene in the lower third of the sill, though subordinate in the higher portions.

Scottish Dolerites and Tholeiites. 2 V > 52° (0), 51°–46° (14), 45°–36° (3), 35°–25° (1), 24°–0° (5). Orthopyroxene, though subordinate to clinopyroxene, is common in the coarse varieties; pigeonite is less common.

TABLE IX · Comparative Classifications of Clinopyroxenes with Molecular Ratio En: Fs. < $^{80}/_{20}$ > $^{50}/_{50}$

Mineral Species		2 V	Av. Wo
Salite		∥(010) > 57°	50%
Augite	*Augite* (1941)	57°–55°; 55°–50°; 50°–45°	45%
Sub-calcic Augite here suggested	*Hypersthene Augite of Holmes (1928) Walker (1940–41) and others*	45°–40°; 40°–35°; 35°–30°	25%
Total Immiscibility Gap of Hess (1941) / *Partial Immiscibility of other Petrologists*	*Gap Hess*		
Pigeonite of Tsuboi (1932) Walker (1940–41) and Hess (1941) emending previous usages and here adopted	*Pigeonite (including also much of the ferroaugite of Hess (1941)) Wager and Deer (1939)*; *Pigeonite Barth (1931) Bogue and Hodge (1931)*; *Enstatite-Augite Wahl (1901) Pigeonite of most Authors*; *Pigeonite of Alling (1936)*	30°–0°; 0 ±; ⊥(010) 0–30°	15%
Clinohypersthene		> 30°	5%

NOTE.—Wager and Deer's (1939, p. 242 and footnote) definition of pigeonite was based on chemical composition (Wo 10%–40%) and not on optical axial angle, for which the above table suggests a mean value. It foreshadowed the possibility of subdivision into metastable pigeonites and stable plutonic pigeonites.

In addition to the above grouped data it may be noted that (with the exception of those for Karroo dolerites) recorded numbers of individual measurements between 40° and 15°, parallel to (010) are:—40° (20), 39° (7), 38° (13), 37° (3), 36° (8), 35° (2), 34° (6), 32° (1), 30° (15), 29° (1), 27° (1), 26° (1), 22° (2), 20° (4), 18° (1), 17° (5), 16° (2), 15° (1).

The notable peak at 30° with few immediately adjacent records suggests that the rarity of such records immediately above 30°, from which Hess inferred the existence of a total immiscibility gap between augite and pigeonite, may arise at least in part from the natural tendency to estimate a value to the nearest round number when the means for determining are not very precise.

Moreover, as Hess (1941, p. 524, Fig. 2 A and B) indicates, omission of reference to the orientation of the optic axial plane in the case of measurements of 2 V near 30° may obscure the relations

TABLE X.

Optic Axial Angles Recorded for Pyroxenes in Representative Volcanic and Hypabyssal Basic and Intermediate Igneous Rocks.

Rocks		Semi-alkaline and Alkaline Basalts, etc.						Normal and Olivine Basalt								Dolerite				Andesite			
2 V		Ap	Ag	Bc	Bm	Cp	Cg	Dp	Dg	Ep	Eg	Fp	Fg	Gp	Gg	H	I	J	K	Lp	Lg	M	Totals*
> 57°	DTS	14	16	5	4	4	6	3	0	9	8	5	3	8	10	2	3	0	1	11	0	5	107
57°–55°	Augite	10	15	3	0	4	10	2	1	6	5	2	1	0	0	6	0	0	1	12	0	4	82
55°–50°		17	5	5	1	1	6	15	8	2	1	1	3	6	8	22	0	11	21	18	0	?	150
50°–45°		16	8	7	3	0	1	15	12	0	6	4	0	5	9	32	10	77	30	49	6	5	295
45°–40°	Subcalcic Augite	4	2	1	3	0	0	9	7	1	0	0	0	0	0	16	4	59	10	26	5	6	153
40°–35°		1	1	0	1	0	0	3	10	0	6	0	0	0	0	14	4	18	0	4	5	4	71
35°–30°		0	0	0	0	0	0	2	3	0	0	0	0	0	0	1	1	18	0	0	0	0	25
30°–25°	Pigeonite	0	0	0	0	0	0	2	6	0	4	0	0	0	0	0	0	—	0	1	3	1	17
25°–0°		0	0	0	0	0	0	5	8	0	0	0	0	0	0	0	0	—	0	4	10	2	29
0° ±		0	0	0	0	0	0	0	7	1	8	0	0	0	0	0	1	43	0	2	5	0	67
0°–30°		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	19	0	0	0	0	23
> 30°	Clh.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Orthop.		0	0	0	0	0	0	13	5	R	0	0	0	0	0	?	5	38	0	118	7	1	Abun.

* The totalled number of determinations of optic axial angles in the several intervals cannot represent the actual relative abundance of the corresponding pyroxene, since very commonly only the values of 2 V in cores and in margins are given in the literature. Intermediate values of 2 V, especially in the group 2 V = 50°–45°

NOTES.

DTS = Diopside, Calcic Titanaugite and Salite. Clh. = Clinohypersthene.

The following are the rock series included in the above:—

A. Phenocrystic (p) and groundmass (g) titanaugites in Late Tertiary basaltic rocks of E. Otago, N.Z. Benson and Turner (1939, 1940), Benson (1942a), Paterson (1942). The so-called orthopyroxene of these papers is olivine.

B. Titanaugite (c = cores, m = margins) in homogeneous or zoned crystals in olivine theralite, Waihola, E. Otago, Turner and Benson (1942).

C. Augite in semi-alkaline and alkaline basaltoid rocks of Pacific and Kurile Island: (p), (g) as above. Barth (1931), Kuno (1935).

D. Augite is often iron-rich basalts of Huzi zone, Japan, sometimes containing olivine with quartz, tridymite, and/or cristobalite: (p) and (g) as above Tsuya (1937). See also Sugi (1937).

E. Augite in normal basalts and olivine andesites of the Pacific, (p) (g) as before (R = rare). Barth (1931). (For more detailed analysis see Edwards, 1935, p. 18.)

F. Augite (p and g) in basalts and olivine andesite of Banks Peninsula, N.Z. Turner, in Benson and Turner, 1939. (No orthopyroxene, see A.)

G. Augite (p and g) in olivine basalt. Auckland, N.Z. Turner, in Benson and Turner (1939). No orthopyroxene.

H. Augite and subcalcic augite in dolerites, etc., N.E. Otago.

I. Pyroxenes in Tasmania dolerites. Edwards (1942).

J. Pyroxenes in the Karroo dolerites measured chiefly by Dr. A. Poldervaart (priv. com.).§

K. Unzoned pyroxene in marginal olivine dolerite. Hallefors, Sweden, showing Gauss variation about the mean value 49°. Krokström (1936).

L. Pyroxene (p) and (g) in Japanese andesites, often containing quartz, tridymite and/or cristobalite and olivine in some cases. Kuno (1936), Tsuya (1937).

M. Pyroxene in Cascade Andesites of Oregon. Bogue and Hodge (1940).

of pigeonite to "augite." Though the data collected into Table X do not lead to as sharp a separation between them as that shown in Hess's Fig. 2B, they support the inference which may be drawn from Walker (1943, p. 518) cited below, that the continuity in the series of clinopyroxenes is least marked beneath rather than above the value 2 V = 30° in the plane parallel to (010).

Table IX illustrates the varying usage that has been attached to the term pigeonite. The conventional usage as denoting clinopyroxenes with 2 V = 0°–45° is that which has been followed by such authors as Winchell, Lacroix, Ford, Kuno and Tsuya. Wahl, Rosenbusch, Flett, Holmes and Fermor are among those who have used enstatite-, bronzite- or hypersthene-augite in about the same significance. While limiting pigeonite to pyroxenes with 2 V < 32° or 30°, Walker (1940, 1941) used "hypersthene-augite" for the more calcic pyroxenes with 2 V = 30°–50° or 52°, which had been included by others within the term pigeonite, but he later (1942) abandoned it. It seems, however, that a new term for such pyroxenes would be useful, and subcalcic augite is here suggested to include augitic pyroxenes with 2 V less than 45°—i.e., all pyroxenes with

§ Values of 2 V in the ranges 31°–25° and 25°–0° in Karroo pyroxenes are here omitted as only five such angles, all doubtfully measured, were noted by Poldervaart. Including some of these and others possibly less accurately observed by earlier workers 10 angles in the range 25°–0° are recorded in the literature. Though 38 measurements of 2 V in orthopyroxenes were made, the number (*fide* Professor Walker) over-estimates the quantitative abundance of this pyroxene.

2 V > 30° hitherto termed pigeonite by most petrologists other than Walker and Hess. An alternative upper limit, 2 V < 48°, suggested but not stressed by Professor Walker in his very generous and helpful letter, would include within the subcalcic augites nearly all the Karroo clinopyroxenes other than pigeonite, and the majority of those in the Tasmanian dolerites other than pigeonite. Time will show which of these or other alternative limits is the most useful, if the recognition of the subcalcic augites as a petrologically significant group should obtain general acceptance.

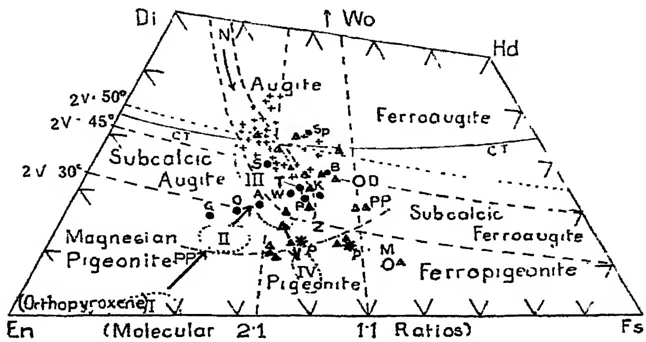
A further suggestion concerning the minimum value of 2 V in subcalcic augites is advanced with diffidence. Walker (1943, p. 518) "is quite prepared to accept 32° as the maximum value for 2 V (in pigeonite), but considers that the limit should be without reference to the orientation of the optic axial plane. In his experience pigeonites with the optic axial plane parallel to (010) are most frequently found as the margins of strongly zoned augite crystals with which they are in perfect optical continuity, and their optic axial angle does not fall much below 32°. They are the result of extreme zoning and show complete gradation into normal augite. Such pigeonites are strongly ferriferous, and lie just below the ferroaugite field in the triangular diagram. Pigeonites with the optic axial plane perpendicular to (010) are of quite a different nature. They may precede augite in the crystallisation of diabases and dolerites, or may come after it, but in both cases the boundary between pigeonite and augite is sharply defined under the microscope, indicating a discontinuity. In the first case the mineral is magnesian, and may be a reaction product of magnesian olivine or of bronzite, in the second it is ferriferous, being a lime-poor equivalent of ferroaugite." As it is desirable where it is practically possible, that mineral nomenclature should express genetic features, and the orientation of the optic axial plane is generally determinable in pyroxenes with 2 V within a few degrees of 30°, it is tentatively suggested that the pyroxenes of the first group distinguished by Walker, including those with 2 V = 30° should be classed with the subcalcic augites, or subcalcic ferroaugite. This may mean that some of the rare pyroxene with 2 V in the plane parallel to (010) is a degree or two less than 30° would be classed as subcalcic augite, and would mean that the composition-range of this group of pyroxenes extends across the narrow, sparsely-tenanted interval immediately above the line of 2 V = 30° assumed by Hess (1941) to be the field of total immiscibility separating augite from pigeonite, and also that the boundary between subcalcic augite and pigeonite lies in the much wider and more sparsely tenanted interval immediately below 2 V = 30° which was assumed by Hess to form portion of the field of continuous variation of pigeonite. The suggestion here advanced as to the upward limit of the pigeonite-field accords, however, very closely with Hess's alternative proposal to accept the line of Wo = 15% as that limit. (See Fig. 5 on p. 83.)

The pigeonites as here limited might be divided on statistical grounds into magnesian pigeonites, pigeonite, and ferropigeonite according as the molecular ratio En:Fs therein is > 2:1, 2:1 < > 1:1 or < 1:1, but any division should be considered on chiefly genetic grounds. The first two members of the above trio are represented

respectively by the early and late pigeonites of Walker and Poldervaart (1941, Fig. 5. See also our Fig. 9), the second and third occur (the third but rarely) in the groundmass of the unusually furruginous Japanese basalts (Tsuya, 1937), but the second also forms phenocrysts or more probably xenocrysts (Kuno, 1936, p. 125) in a Japanese andesite and ferropigeonite (Wo_9 En_{40} Fs_{51} in molecular ratios, M on Fig. 8) forms rounded phenocrysts in the semi-vitreous dacitic inninmorite of Mull (Hallimond, 1914; Thomas and Bailey in Anderson and Radley, 1916, p. 209). The conditions under which iron-rich pigeonites may have formed have been discussed by Holmes and Harwood (1928, pp. 507–8), Bowen and Schairer (1935, p. 203), Kuno (1936, p. 149), Wager and Deer (1939, p. 254), and Hess (1941, pp. 589–591), who (p. 581) concludes with Phemister (1934, p. 58) that in general " hypersthene with oriented plates is characteristic of *slowly cooled* intrusives, and pigeonite " (as here recognised) " is absent in them. Pigeonite is characteristic of *rapidly cooled* extrusives, and hypersthene with oriented plates is absent in them. Whereas the intermediate type, the fine grained intrusives, may show both forms. In those rare cases where pigeonite began to crystallise in depth and the magma containing it was suddenly extruded, pigeonite phenocrysts will be found." Walker and Poldervaart (1941, p. 132) remark that " there must be instability boundaries " [other than those defined on the basis of chemical composition by Wager and Deer (1939, p. 255)] " in the intervening zones between the volcanic rocks in which all compositions of pigeonite " (as here) " are stable, and the plutonic rocks, in which only the iron-rich varieties are to be found." Edwards' (1942) views are re-stated below in his generously contributed Appendix II.

Dr. F. J. Turner has suggested in conversation with the writer, that the relations of pigeonite, subcalcic augite and augite, in so far as they are not affected by magmatic water (see below) may in some measure be likened to those of orthoclase, anorthoclase and albite, and may perhaps be expressible by an equilibrium-diagram resembling that drawn by Barth (1939, p. 24, Fig. 8) for these feldspars on the basis of Schairer and Bowen's work. Such an equilibrium-diagram for clinopyroxenes would show on either side in the lower (plutonic) temperature-range the boundaries of the stability-fields of pigeonite and (diopsidic?) augite respectively, there possessing only limited miscibility. Traced to higher temperatures these boundaries would converge and eventually join, possibly at a " dry melt " temperature higher than the natural crystallising temperatures of basalt. Above this junction the stability-fields of the three clinopyroxenes would merge continuously into one another. Below it, at temperatures at which most basalts and dolerites crystallise, though subcalcic augite is often formed, it is metastable. This suggestion seems to accord with the observations both of Bowen and Schairer (1935) and of Hess (1941), and to afford a synthesis of their divergent explanations.

The application of the above suggestions to the classification of clinopyroxenes in several rock-series is illustrated by Fig. 9, in which the compositions of representative clinopyroxenes are plotted in weight percentages, the molecular percentages being indicated by the



9. Nature and relation of pyroxenes in several series of rocks. For explanation see text.

divisions along the margins. The limits drawn by Hess (1941, p. 518) for the fields of diopside, endiopside, salite, ferrosalite and hedenbergite are omitted. The small crosses indicate the optically determined compositions of phenocrysts in Japanese non-alkaline basalts and andesites, showing their normally augitic to subcalcic nature and lack of continuous variation towards the rare pigeonite phenocrysts indicated by the two larger asterisks marked by *p*. Triangles indicate the optically determined compositions of groundmass pyroxenes in the same Japanese rocks and demonstrate the continuous variation from the lower calcic range of augite through subcalcic augite to pigeonite and rarely ferropigeonite, for these rocks are abnormally rich in iron. (Data from Tsuya, 1937.) Black circles show the average normative compositions of the representative rock series considered in Table VIII as follows:—A = Antarctic dolerites; B = Plateau basalts; G = German tholeiites; K = Karroo dolerites; O = Otago dolerites, basalts and tholeiites; P = Palisadan dolerites; S = Scottish and North of England dolerites and tholeiites; Sp = Spitzbergen dolerites; T = Tasmanian dolerites; W = Watchung basalts, the effusive products of the Palisadan magma. The black rings indicate the chemically determined composition of:—D = the pyroxene from the Deccan basalt submitted to X-ray spectrographic examination (see below) and M = the ferro-pigeonite in the inninmorite of Mull. I, II, III and IV show the fields of composition-range for successive generations of pyroxene in the Karroo dolerites as determined optically by Walker and Poldervaart (1941, Fig. 5) being respectively I = initial hypersthene, II = early magnesian pigeonite, III = " hypersthene augite "—i.e., subcalcic augite (with a little augite poor in lime), IV = late-formed pigeonite. It will be noted that the average composition of the modal pyroxene in the Karroo dolerites is less ferruginous than the average normative composition K. It will further be seen that the sequence I-II-III is almost exactly that found by Kuno (1933) in a Japanese cristobalite-bearing olivine, augite-hypersthene basalt and plotted by Alling (1936, p. 218), whose " Pigeonite No. 2 " (with 2 V = 48°–50°) in Kuno's and our view [and indeed on his own classification (Alling, 1936, p. 102)] is an augite poor in lime. It lies on Alling's (*op. cit.*, pp. 100, 218) cotectic line (CT–CT on our Fig. 9) near the turning point in the

differentiation-trend of the Karroo pyroxenes from an increasingly to a decreasingly calcic composition, the physico-chemical significance of which has apparently not yet been discussed. There seems little indication in Fig. 9 that Tsuboi's (1932, p. 75) " Two pyroxene line " (PP–PP) has significance in regard to the development of these dolerite pyroxenes. The field and arrow N.Z. on Fig. 9 show the composition-range and differentiation-trend as determined for the pyroxenes of the Mid-Tertiary dolerites, tholeiites and basalts of Otago. In spite of the close approach of the average bulk composition of these rocks and of average normative compositions of their pyroxenes to those of the rock-series taken by Kennedy (1931, 1933) to be typical of his tholeiitic magma-type (see Tables VII and VIII above), the differentiation-trend of the Otago pyroxenes is that of the pyroxenes in the basic members of Kennedy's olivine basalt magma-type, and is perpendicular to the differentiation-trend I-II-III of the pyroxenes in rock-series taken by him to be typical of his tholeiitic magma-type, a feature which remains true even if we consider only the quartz-bearing dolerites among the Otago rocks. It would seem, therefore, that some significant factors have been omitted from Kennedy's discussion, and it suggested that the effect of high content of water in crystallising magmas may be among these. Phemister (1934, p. 63) suggested that since " the nature of the equilibrium in the pyroxene group changes with the approach to plutonic conditions of crystallisation of the magma " (see above), " and since also the amount of water in the magma as it reaches saturation varies with the position of the mass in the crust, the petrological evidence leads to the suggestion that water may be the controlling influence in pyroxene-equilibrium." Bowen and Schairer (1935, p. 201) doubted " whether the necessary quantity of volatiles could have been present and yet leave no evidence of their presence in the formation of hydrous phases such as amphibole, which are often entirely lacking." But, as has been noted, though amphibole is extremely rare in our rocks, there is abundant independent evidence of the former presence of much magmatic water. It may, perhaps, be this which, at a late stage in magma-consolidation, has determined the almost rectangular change in the direction of differentiation-trend of the Karroo pyroxenes.

APPENDIX II.

A Note on the Crystallisation of Pyroxenes.

By A. B. Edwards.

" The progressive changes in composition developed in pyroxenes crystallising from a differentiating magma are governed by two dominant factors: (1) the composition of the residual magma at any stage, and (2) the stability, or otherwise, of the molecular lattice structure of the pyroxene concerned.

" Recent studies by Hess (1941) and by Edwards (1942) indicate that under conditions of slow cooling, which permit the development of stable pyroxenes, the molecular structure of the pyroxene is the more important factor of the two in deciding the trend of change of composition. The difficulties of substituting Fe^{++} (ionic radius 0·83A°) for Ca^{++} (ionic radius 1·06A°) in the pyroxene structure without undue distortion of the crystal lattice, leads to the formation

of two immiscible series of pyroxenes, which crystallise side by side. The width of the immiscibility gap between these two series is a maximum in slowly cooled magmas, and decreases as cooling becomes more rapid, until in rapidly cooled rocks such a thin lava flows, sills and dykes, it is reduced to zero.

"In rapidly cooled rocks, the single pyroxene that forms is in a metastable condition. Under such conditions Fe^{++} can substitute for Ca^{++} in the lattice structure of the pyroxene without any undue distortion resulting. As a result the molecular structure of the pyroxene ceases to be the dominant factor controlling its progressive changes in composition; and changes in composition shown by the pyroxene simply reflect the changing composition of the residual magma. Examples of the change induced by a sudden increase in the rate of cooling on the composition of the pyroxene have been provided by Tsuboi (1932) and C. N. Fenner (1938). Tsuboi records instances where augite and orthopyroxene crystallising as phenocrysts have given place to a single "pigeonite" of intermediate composition crystallising in the groundmass. Fenner described an instance where magnesia-rich orthopyroxene crystallising as phenocrysts has given place to a groundmass pyroxene which is lime-rich augite and which more nearly reflects the composition of the residual magma as represented by an analysis of the aphanitic groundmass, than does the earlier formed orthopyroxene.

"Since the prevailing change in composition in most residual magmas of basaltic character is towards an enrichment in iron relative to magnesium, the change of composition of the metastable pyroxene is generally towards an enrichment in iron in the marginal zones of the crystals, regardless of whether the original pyroxene is calcium- or magnesium-rich. This is shown by the results obtained by Barth (1931, 1936), by Kuno (1935) and still more recently by the data recorded in the foregoing paper."

To this the writer (W.N.B.) may add that Dr Edwards (1942, p. 599) recalls that the formation of metastable subcalcic pyroxene on relatively rapid cooling is in accord with the results of Bowen and Schairer's (1935) experimental work, and that there is a tendency for such pyroxenes gradually to change with separation and inversion to enstatite of the $MgSiO_3$ in excess of diopsidic proportions. That this may occur submicroscopically seems indicated by X-ray powder spectrography. An apparently homogeneous pyroxene separated from the Deccan basalts and found by chemical analysis to have the composition Wo_{25} En_{37} Fs_{38} (D in Fig. 9 herewith) was examined by X-ray spectrography (Wyckoff, Merwin and Washington, 1925). "Its predominant line-pattern is diopside-like. Other lines are present, however, which could be the principal ones of an enstatite-like structure. It is thus compatible with the observed measurements, though these measurements do not furnish final proof that this Indian augite is an intimate mixture of materials having these two structures. The density of such a mixture could be calculated on the assumption that the diopsidic content is normal with respect to calcium, and that the (Fe, Mg) in excess of the amount necessary to combine with it is present as hypersthene. The density calculated on this basis is close to the observed density."

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Some Igneous Rocks from the New Plymouth Area.

By C. Osborne Hutton,
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[*Read before the Wellington Branch, Royal Society, October 21, 1943; received by the Editor, March 22, 1944; issued separately, September, 1944.*]

Summary.

The mineralogy and petrology of the andesites, dacites, and hybrid rocks of Paritutu, Mataora Island, and Ngataierua Point, have been investigated. In addition, a study has been made of a porphyrite encountered during boring operations at No. 1 Devon Well of New Zealand Petroleum Co., Ltd. In order to explain the distribution of, and structures displayed by these rocks, a cone-sheet theory has been enunciated in which it is assumed that Paritutu and the Sugar-loaf Islands are merely remnants of former steeply dipping cone-sheets, the igneous material having been injected upwards along tension cracks from a magma now represented by the porphyrite sill.

Introduction.

Lying approximately two miles west of the centre of New Plymouth are the Sugar-loaf Islands, composed of solid dacitic igneous material; and on the mainland adjacent to this ring of islands is a prominence, also dacitic, known as Paritutu (Pl. 14); this pinnacle, rising almost vertically to 505 feet from the sea-level, is usually included with the Sugar-loaf Islands, under the name of "Sugar-loaves." The Devon Well is situated a mile and a half south-east of Paritutu, and the entire area dealt with lies within Paritutu Survey District.

According to E. de C. Clarke (1912, p. 14) the igneous rocks of this area include lava-flows, tuffs, and agglomerates belonging to the Pouakai Series (presumably Pliocene and Pleistocene). He considers that this series rests uncomformably upon the Onairo Series of sandstones, claystones, and limestones, whereas the lava flows and fragmental igneous material associated with the activity of the nearby extinct volcano Egmont, post-date the Pouakai Series. The present writer is concerned only with the igneous rocks of the Sugarloaves and the Devon Well, and no work has been carried out on the agglomerates and other fragmental rocks.

Structures.

In outcrops well displayed in the bay immediately north-east of Paritutu Trigonometrical Station, a system of joints is well developed. A series of major joint planes, slightly arcuate in trend, strike at approximately 35° with a dip to the north-west of 45°, and within these planes there is a noteworthy parallel arrangement of hornblende crystals with the long axes in the direction of dip. It is assumed that the hornblende crystals are parallel to flow lines and that the steeply dipping joint planes are parallel to flow surfaces. Therefore these joint planes are probably to be correlated with Cloos' (1922) longitudinal or S – joints (*Spaltseite*), which may be defined as steeply dipping joints, coinciding with the foliation. At this

juncture it should be noted that the S – joints of Cloos are not to be confused with the s – planes of Sander (1930), though Balk (1937, p. 36) believes that Sander's very broad definition would include longitudinal joints.

A second series of joints not so well developed as the first, strike in approximately the same direction but dip to the south-east at 45°–50°—that is, perpendicular to the lineation or trend of the prismatic amphibole crystals. It would seem, therefore, that these joint planes are the equivalent of Cloos' cross or Q – joints (*Querklufte*). However, these joints, which must be regarded as equivalent to tear or tension fractures, are not open, nor are they filled with the usual veneers of hydrothermal or secondary minerals that are so common in these structures (Balk, 1937, p. 27). In places a slight orientation of crystals was observed along a plane striking at 120° and dipping at about 45°. On the north-eastern side of Ngataierua Point itself, well developed S – joints strike at 50°–60° and dip north-west at approximately 30°. In places these planes were observed to change their attitude gradually, and if traced some distance the dip increased until nearly vertical. A second set of planes also with a 50°–60° strike, the Q – joints, cross the former series and dip to the south-east at 45°. Again the orientation of the hornblende is a noticeable feature with the crystals oriented much as before—that is, approximately in a plane parallel to the S – joints but with a somewhat steeper dip.

Owing to the weather conditions at the time of the writer's visit, it was possible to examine neither the sea-wall of Paritutu nor the outer ring of islands other than Mataora and Motu-o-Tamatea. From the Ngataierua Point, however, a poorly developed columnar structure was clearly seen on the sea-side of Paritutu; this development is roughly vertical but in very many places the columns are bent and contorted as if movement of magma in a viscous or semi-solidified state had occurred.

On Mataora and Motu-o-Tamatea Islands similar poorly developed, vertical columnar structures were observed. Nearly east-west and nearly vertical jointing and shear-planes are prominent. Weathering solutions moving along these joints and shear surfaces have deeply altered the rocks on either side and hydrated iron oxides are liberally present. Seeps are numerous along these planes and hydrated iron oxides are at present being deposited. A most striking feature of all the outcrops in this locality is the size and abundance of the plagioclase phenocrysts; these commonly reach 10 mm. in length.

In the Devon Well, a porphyrite was encountered at a depth of 9,388 feet and drilling was continued in this material for a distance of 31 feet. Of course little can be said in regard to the structure of this mass, but the writer considers it to be a sill rather than a dyke or flow. This belief is supported first by the presence of a zone of indurated and slightly baked mudstones and siltstones for a distance of several hundred feet above the porphyrite; and secondly in the cores taken from the well at this point 80–90% of the hornblende crystals were observed to be oriented in a horizontal plane—that is, normal to the direction of the bore hole,

ORIGIN OF PARITUTU AND THE SUGAR-LOAF ISLANDS.

It was E. de C. Clarke's (1912, p. 21) opinion that the igneous rocks of the "Sugar-loaves" were lavas. After some recent work the writer does not favour this view, for none of the field evidence is in support of it; on the contrary, most of the visible structural features such as major jointing and lineation, point to injection of the igneous rocks along steeply dipping planes. Any hypothesis that is advanced to explain the mode of emplacement of the igneous rocks must take into account the following points:—

1. As will be observed later, the chemical similarity between the porphyrite at the bottom of the Devon Well and the main mass of dacitic rocks of which Paritutu, Mataora Island, Ngataierua Point, and presumably the other islands are composed, is significant.

2. Hydrothermal solutions have been very active in both groups of rocks.

3. The geographic distribution, shape, and orientation of the Sugar-loaf Islands and Paritutu is of importance (Text fig. 1).

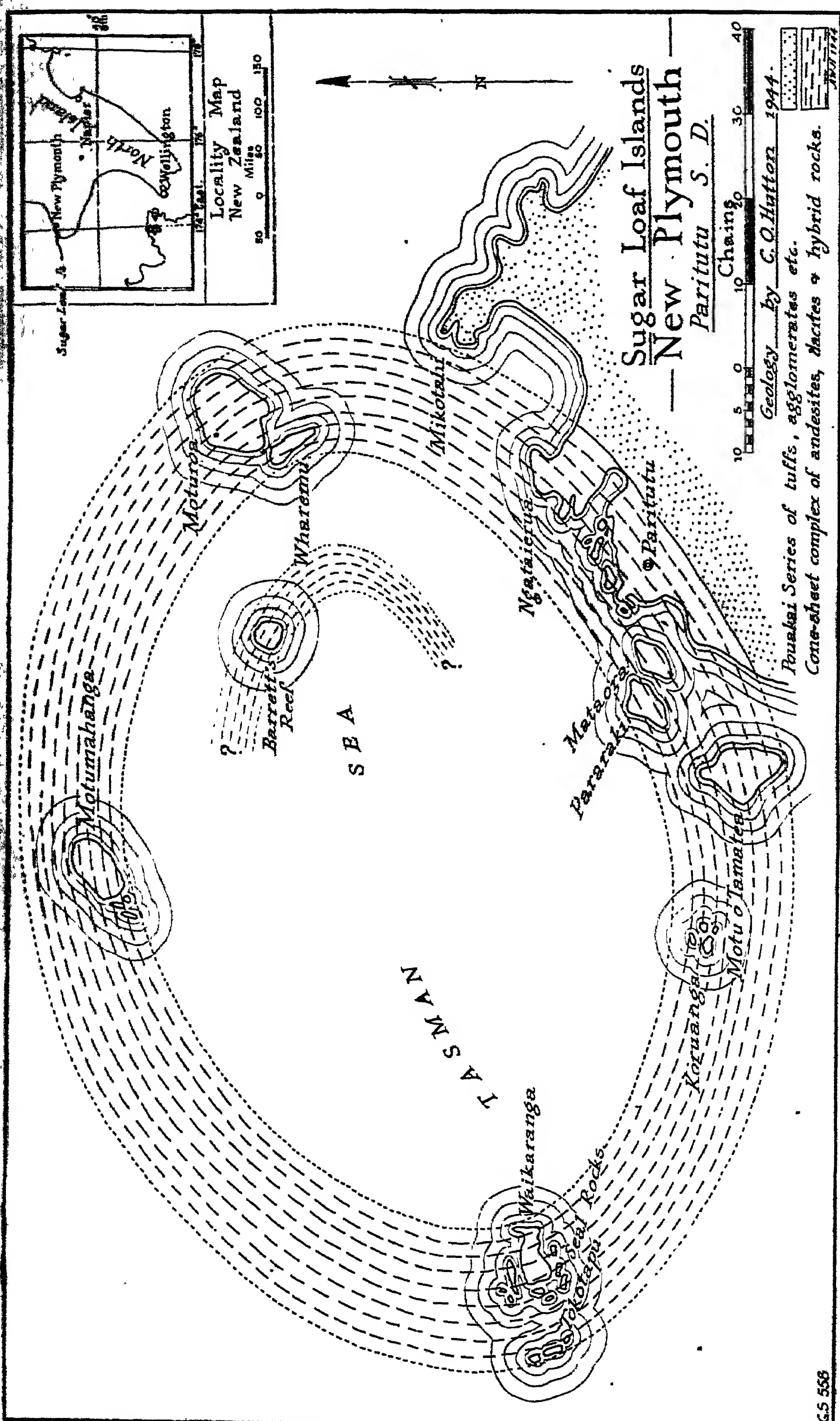
4. Drilling was undertaken at a point approximately 10 chains east of Paritutu, and this bore, after passing through a thin, superficial covering of Pouakai Series, went to a depth of nearly 3,000 feet in fairly homogeneous mudstones, without encountering any massive igneous material. If Paritutu was made up of dacite flows, their eastward extension would certainly be expected.

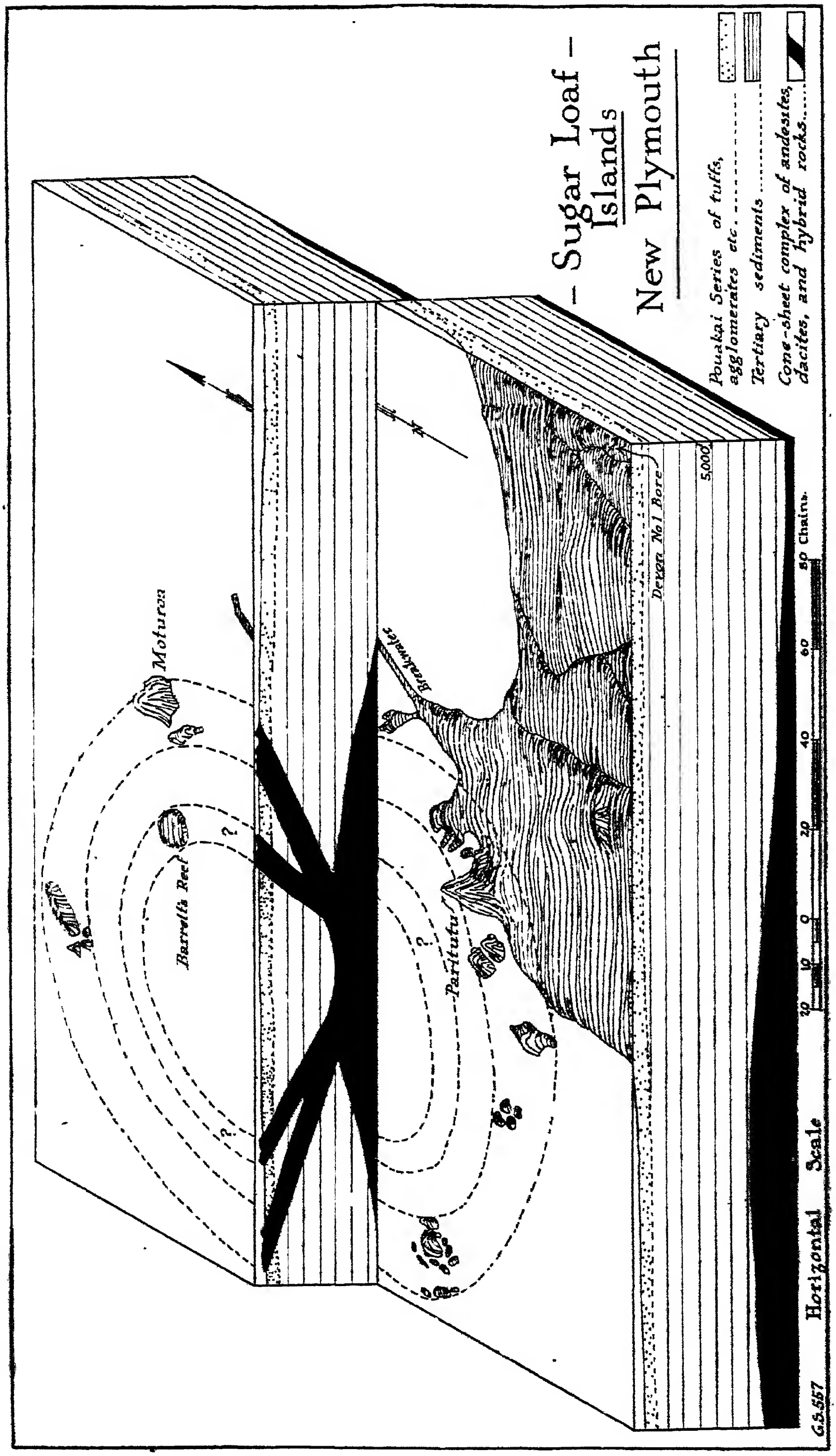
5. Known oil seepages have been observed in a number of places close to the Sugarloaf Islands and in all cases these were located on the outer periphery of the elliptical zone in which the islands and Paritutu lie. To the writer's knowledge, oil seepages are unknown within this zone, and if the hypothesis to be advanced is correct, then seepages are not to be expected here.

In the writer's opinion the sequence of events for the igneous rocks may be summarised as follows:—

An intrusion of porphyrite into Upper Tertiary sandstones and siltstones in the form of a sill or laccolith took place. The maximum thickness of this intrusion is not known, but the very minor contact effects that were brought about in the surrounding sediments seem to indicate either a relatively low temperature or very modest volume of magma or both. A cupola, or dome-like, upward extension of this magma reservoir may have developed as a result of the magmatic pressure overcoming the strength of the relatively thin crustal covering. Tension cracks would then have tended to open up in the overlying sediments in a fashion comparable to that postulated by E. M. Anderson (1924) to explain the development of cone-sheets in Mull (Text fig. 2). Up these tension cracks the andesitic magma has been injected with the development of a series of cone-sheets. Subsequent erosion has reduced these cone-sheets, the Sugarloaves being the remnants of the former continuous outcrops. In spite of the abundance of volatiles that appear to have existed in the porphyrite magma, andesites, and dacites, the relief of pressure on the magma chamber does not appear to have given rise to any explosive ejection of pumiceous or tuffaceous debris, unless, of course, these have been entirely removed by erosion. Nor is there any suggestion that with solidification of the gas-poor magma a collapse of the roof of the magma chamber has occurred, producing a small caldera.

A close study of the islands suggests the existence of at least two cone-sheets, although surface traces of additional ones may have


Sugar Loaf Islands
New Plymouth
Paritutu S. D.
Chains
Geology by C.O. Hutton 1944.
Pouakai Series of tuffs, agglomerates etc.
Cone-sheet complex of andesites, dacites & hybrid rocks.
Locality Map
New Zealand
Miles
New Plymouth
Napier
Wellington
North Island
Sugar Loaf Is.
N
Mikotahi
Moturoa
Wharemu
Barrett's Reef
Ngataieruа
Paritutu
Motumahanga
Mataora
Pararaki
Motu o Tamatea
Koruanga
Waikaranga
Seal Rocks
Tokotapu
TASMAN SEA
G.S. 558



TEXT FIGURE 2.

been completely removed by erosion. If one allows a regular dip of 40°–50° for the cone-sheets a simple construction indicates the depth of the cone-sheet foci to be about 5,000 feet. At this point, therefore, a considerable upward extension of the magma chamber must be present for the upper surface of the porphyrite body was touched only at 9,388 feet in the Devon No. 1 bore, situated just two miles south-east of the centre of the cone-sheet structure (south-east corner of Text fig. 2).

The thickness of the cone-sheets deserves brief comment. The outer sheet (Text fig. 2) appears to have a thickness of approximately 600 feet to 700 feet, whereas the supposed inner one would not exceed 200 feet to 250 feet. These sheets are much thicker than the well-known sheets of Ardnamurchan (Thomas, 1930, p. 176), where they do not exceed 50 feet, although the Beinn Chreagach Mhor sheet in Mull reaches a maximum width of about 200 feet (Bailey, 1924, p. 238). However, examples of very wide cone-sheets are not lacking, and the quartz porphyry sheet of Kudaru Hills, Nigeria, with a true maximum thickness of 2,800 feet, may be quoted (Bain, 1934, p. 211).

MINERALOGY OF THE PARITUTU-DEVON WELL ROCKS.

Plagioclase.

Plagioclase feldspar is the dominant mineral in all of these rocks, and forms particularly conspicuous phenocrysts in the Paritutu-Sugar-loaf Islands group of dacites and andesites. Twinning on the albite and Carlsbad laws is commonly developed, but pericline twinning is much less usual. Twinning on the albite-ala B law was observed in one case, but other types of twinning have not been noted, although they may be present, for an exhaustive study of feldspar twinning was not made. The composition in all cases was determined with the universal stage following the methods of Nikitin (1936) and occasional check determinations by R.I. methods were carried out. Except for the occurrence of very calcic feldspar in curious hybrid rocks (P. 9339), the plagioclase is always andesine; in the Devon Bore porphyrite the feldspar is sodic andesine with an average composition of $An_{30\text{-}33}$, while in the Paritutu group the composition is somewhat more basic, being about $An_{34\text{-}50}$. In the hybrid rocks bytownite is the only plagioclase present, with a composition varying from $An_{73\text{-}80}$.

In the normal dacites from the Paritutu area zoning on an elaborate scale is a conspicuous feature, and several types of zoning have been observed. First there is the phenocryst showing a gradual change from a rather calcic core or nucleus to a peripheral zone of sodic character. In the porphyrite from the Devon Well, several universal stage determinations indicated a range from An_{42} for the nucleus to An_{27} for the periphery, in an extreme case, while An_{30}–An_{33} appeared to be the more usual range. A similar type of zoning is seen in the Paritutu group as well, which, following Larsen's (1938, p. 229) simplification of Homma's (1936) classification, has been termed normal. A much more complex development in zoning is a feature of the plagioclase phenocrysts of the Paritutu group. This consists of a fairly regular rhythmic type of zoning comparable to the oscillatory type which Larsen (1938, p. 229) states is the commonest arrangement in the San Juan andesites and allied lavas. In two particular

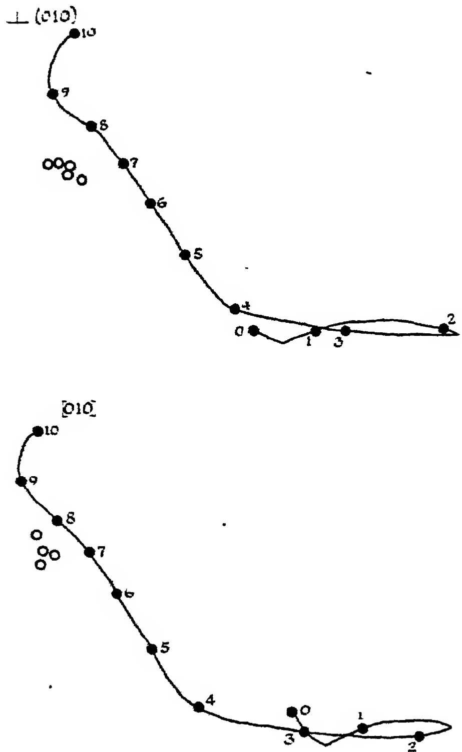
phenocrysts the change in the percentage of anorthite was observed to vary as follows: central zone, An_{44} varying to An_{40} on the outer rim of this area; intermediate zone An_{44}–An_{40}; and for the peripheral zone the variation was more pronounced with An_{44}–An_{34}. In the hybrid type with very calcic plagioclase—viz., bytownite, zoning of this type is also present but in occasional crystals where this does not occur a very thin sodic envelope has been precipitated around the anorthite-rich core.

The cause of the development of the normal type of zoning is clear enough, and the course of crystallization can be readily determined from the albite-anorthite phase diagram (Bowen, 1913) but the normal oscillatory type, on the other hand, presents a more difficult problem. Phemister (1934) has advanced the theory of diffusion-reaction control, whereby crystals more calcic than the initial liquid separate, resulting in the production of sodic liquid surrounding the crystals. These crystals are then presumed to react with this sodic liquid causing a " concurrent rise of the An. Ab. ratio in the liquid both through reaction and through diffusion." Finally a renewed deposition of calcic plagioclase results. Hills (1936, p. 50), in the present writer's view, correctly drew attention to a fallacy in Phemister's argument, particularly the latter's hypothesis that on account of a rise of temperature resulting from crystallization, reaction between plagioclase and the sodic enveloping liquid would produce a *less* sodic zone to the crystals. Hill's view (1936, p. 52) of the origin of what he terms oscillatory—normal zoning does seem to fit the case more accurately. He considered that crystallization, having commenced under conditions of equilibrium, proceeds gradually and produces, through diffusion, a crust surrounding the crystal itself, and a zone in the adjoining liquid that is enriched in soda. Concomitantly with this, the liquid beyond the sphere of reaction becomes supersaturated with lime. Crystallization of plagioclase is now slow or may have ceased altogether; but, when diffusion has increased the concentration of lime in the zone immediately adjacent to the crystals, calcic-rich material will again be precipitated.

When the twinning axes of measured plagioclase phenocrysts from some of the New Plymouth rocks are plotted on Nikitin's (1936, Pl. VII) useful diagram an important and constant angular variation from the standard Reinhardt-Nikitin curves was found to exist. This displacement of the poles was most noticeable in the hybrid rocks (P. 9339) of Mataora Island. The position of poles of a number of plagioclase phenocrysts twinned according to the albite law have been plotted in Text fig. 3 in order to show their position relative to the $\perp$ (010) curve, and four points are also plotted for crystals in which pericline twinning is developed. This shift of the poles from the standard curves has been noted previously in a number of cases. In Otago, Benson and Turner (1940) considered a pronounced displacement of the twinning axes in the plagioclase of a series of mugearites as due to considerable orthoclase in solid solution.

Both Barth (1931) and Barber (1936) showed that intense heating would cause a shift or dispersion of the twin poles of plagioclase, although Barber (1936a) after some later work, somewhat reversed his opinions. However, a number of European workers—viz., Kohler

(1941, 1942), Tertsch (1941, 1942), and Scholler (1942) have recently published their researches on this problem, and they indicate that the distinction must be made between high and low temperature plagioclases, while Scholler (1942) particularly points out that the difference in optical orientation of natural and artificially heated plagioclase is not due to any loss of alkali. Similar dispersion of the poles of the twinning planes has been described by Larsson (1940) in the plagioclases of volcanic rocks from northern Patagonia, and he considered (*loc. cit.* p. 367) that it is " a property characteristic of the plagioclase phenocrysts of intermediate effusive rocks. Such being the case, it is probable that the rapid fall of temperature from the intratelluric to the effusive stage is to be held responsible for the differences as against the plagioclases of the rocks crystallized during slow and tolerably continuous cooling." Further, the effect of potash in the plagioclase is, Larsson believes, a problem that requires special investigations. Recently Benson (1944, pp. 74–75) has discussed similar variations in connection with plagioclases in the Tawhiroko sill, near Moeraki.



TEXT-FIG. 3.

Standard curves after Nikitin (1936) showing abnormal displacement of twin axes. ⊥ (010) (upper) and [010] (lower), in plagioclase phenocrysts from basified dacite (P. 9339), Mataora Island:

In the rocks from the New Plymouth area this angular shift of twin axes, as stated previously, seemed to be most noticeable in the bytownite phenocrysts of the hybrid or basified rocks, less noticeable

ance in the plagioclase of the porphyrite of the Devon Well. As will be seen later volatile substances have been very abundant in the magmas that produced the Paritutu-Sugar-loaf Islands rocks; thus, in view of the possibility of high temperatures being produced here by oxidation of volatile substances on escape from the magma, the displacement of the poles of the twin axes from the standard curves of Nikitin, based on plagioclases from crystalline schists, pegmatites, and plutonic rocks, that is, low temperature plagioclases, is in agreement with the most modern theory.

AMPHIBOLES.

A greenish-brown hornblende in stout acicular crystals is the most abundant mafic constituent of the porphyrite, and dacites of the New Plymouth area. Typical amphiboles have been separated from two rocks (viz. P. 9332, 9337) by electromagnetic and centrifuge methods, and the analyses made by Mr. F. T. Seelye are quoted in Table I (Nos. 1–2).

TABLE I.

Analyses of Amphiboles.

	1	2	3	4	5
SiO_2	41.41	41.96	43.95	45.07	39.01
Al_2O_3	13.39	12.15	11.40	13.82	13.60
Fe_2O_3	4.94	6.98	4.69	1.82	5.25
FeO	9.89	9.75	9.02	10.58	7.42
MgO	11.63	10.36	13.73	12.74	11.73
CaO	11.81	11.29	11.12	11.68	12.05
Na_2O	2.29	1.98	2.08	2.67	2.51
K_2O	0.68	0.80	0.86	0.33	1.11
H_2O+	2.05	2.04	0.79	0.70	0.98
H_2O-	0.03	0.11	—	—	0.19
TiO_2	1.95	2.00	1.81	0.60	6.05
MnO	0.30	0.44	0.14	0.16	0.14
V_2O_3	0.06	0.06	—	—	—
Cr_2O_3	0.015	0.01	—	—	—
BaO	0.02	0.02	—	—	0.03
SrO	0.03	0.02	—	—	—
F	0.10	0.12	nd.	—	nil
	100.29	100.09	99.59	100.17	100.07
O for F	0.04	0.05			
	100.25	100.04			

	No. 1	No. 2
Sp. Gr.	3.22 ± 0.01	3.22 ± 0.01
α	1.666 ± 0.003	1.670 ± 0.003
β	1.680	1.684
γ	1.687	1.695
$\gamma - \alpha$	0.021	0.025
$\gamma \wedge c$	70–78°	64–74°
2 V	15–17°	10–12°
α	Pale yellowish-green.	Pale yellowish-green.
β	Deep brownish-green.	Deep brownish-green.
γ	Deeper brownish-green.	Deeper brownish-green.
Absorption	$\gamma > \beta > \alpha$	$\gamma > \beta > \alpha$

(1) P. 9332. Porphyrite, Devon Well, Paritutu S.D. Analyst: F. T. Seelye.

(2) P. 9337. North-west extremity of Ngataierua Point, Paritutu S.D. Analyst: F. T. Seelye.

(3) Green hornblende from andesite dyke cutting Potosi volcanics. (E. S. Larsen *et al.* 1937, p. 895, Table IV, column 3).

(4) Hornblende from zoisite-amphibolite, Nieripeivi, Vasterbotten. Analyst: N. Sahlbom. (T. Du Rietz, 1935, p. 179, Table XIV).

(5) Kaersutite, Leith Valley Quarry, Dunedin. Analyst: F. T.

For the sake of comparison, analyses 3, 4 and 5 have been included in Table I, and it has been impossible to find amphiboles that correspond more closely, for both of the New Plymouth hornblendes appear to be unusually high in alumina. Actually the New Plymouth hornblendes are not greatly dissimilar from some analyses of kaersutite, the notable difference is, of course, the high titanium content and the low value for water evolved at a temperature in excess of 105° C. of the latter. It was observed in a few cases that the normal hornblende developed a brown to reddish-brown colour, often zonally, and the most noticeable optical change accompanying this was a marked decrease in the angle Z $\wedge$ c. These changes might possibly be due to an increase in the amount of TiO_2 in the brown types, and if this is so, such amphiboles must have compositions approaching closely that of kaersutite.

Using Warren's (1930) extended amphibole formula, the analyses of the two analysed hornblendes have been calculated on the basis of 24 (O, OH, F) atoms to the unit cell (Table II).

TABLE II.—CALCULATION OF FORMULAE OF HORNBLENDES.

Hornblende P. 9332.

	Wt. %	No. of Metal Atoms on Basis of 24 (O, OH, F).		
SiO_2	41.11	6.075		8.00
			1.925	
Al_2O_3	13.39	2.324	0.399	
TiO_2	1.95	0.213		
Fe_2O_3	4.94	0.550		4.98
FeO	9.89	1.215		
MgO	11.63	2.572		
MnO	0.30	0.035		
CaO	11.81	1.872		
Na_2O	2.29	0.461		2.45
K_2O	0.68	0.124		
H_2O+	2.05	2.022		2.07
F_2	0.10	0.053		

Formula: $(OH, F)_{2.07}$ $(Na, Ca, K)_{2.45}$ $(Mg, Fe'', Fe''', Ti, Mn, Al)_{4.98}$ $[(Si, Al)_8 O_{22}]$.

Hornblende P. 9337.

	Wt. %	No. of Metal Atoms on Basis of 24 (O, OH, F).		
SiO_2	41.96	6.229		8.00
			1.771	
Al_2O_3	12.15	2.120	0.349	
TiO_2	2.00	0.223		
Fe_2O_3	6.98	0.784		
FeO	9.75	1.212		4.91
MgO	10.36	2.290		
MnO	0.44	0.053		
CaO	11.29	1.791		
Na_2O	1.98	0.570		2.50
K_2O	0.80	0.143		
H_2O+	2.04	2.014		2.06
F_2	0.12	0.053		

Formula: $(OH, F)_{2.07}$ $(Na, Ca, K)_{2.43}$ $(Mg, Fe'', Fe''', Ti, Mn, Al)_{4.98}$. $[(Si, Al)_8 O_{22}]$.

In both these hornblendes the Y, Z and (O, OH, F) groups appear to fit Warren's formula satisfactorily, and in both cases an

important amount of aluminium replaces silicon in the tetrahedral chains. Warren (1930, pp. 508–509) has pointed out that when about one-quarter of the silicon is replaced by aluminium in hornblende, the figure for the (Na, Ca, K) group may increase to nearly 3·0. However, this is not exactly the case with the New Plymouth amphiboles, for although there is a tendency for the (X) group to increase in value beyond 2·0, in neither case is this increase as great as Warren (1930) contends in view of the important substitution of Si by Al ions. This apparent anomoly has been recognised in other common hornblendes by Deer (1938, p. 69), and the present writer agrees with Deer's conclusion that the value of the (X) group appears to be far more dependent upon the amount of alkalis in the hornblende composition than upon the Si/Al replacement.

DIOPSIDE.

The clinopyroxene in the porphyrite from the bottom of the Devon Bore is subordinate to the hornblende, and it usually occurs in small equant granules. Owing to the presence of a faint, but distinct, green colour in the mineral it was decided to separate it in the pure state and obtain an analysis. The separation was accomplished by centrifuging the rock powder (— 200, + 250 mesh) in methylene iodide and methylene iodide-tetrabromoethane mixtures.

TABLE III.—ANALYSIS OF CLINOPYROXENES.

	1	2	3	4
SiO_2	49.90	49.57	50.40	49.98
Al_2O_3	3.18	3.82	1.63	4.67
Fe_2O_3	3.10	2.00	2.06	0.25
FeO	7.65	6.59	9.74	9.80
TiO_2	0.92	2.05	1.13	1.16
MgO	11.77	13.75	13.37	12.72
CaO	21.87	21.44	20.65	21.02
Na_2O	0.71	0.69	0.66	0.53
K_2O	0.15	0.08	0.23	0.16
H_2O+	0.45	0.10	0.51	0.20
H_2O-	0.20	0.02		0.09
MnO	0.58	0.13	0.09	0.33
	100.48	100.33	100.47	100.00
α :	1.684	1.690	1.691	1.695
β :	1.691	1.697	1.697	1.702
γ :	1.710	1.715	1.718	1.722
$\gamma - \alpha$:	0.026	0.025	0.027	0.027
Pleochroism	very poor	very weak	—	weak
2 V :	56°	52–54°	43°	43°
$Z \wedge c$:	44°	42°	51–66°	41°
Sp. Gr. :	3.33	3.34	—	3.38

(1) Diopside from porphyrite, P. 9332, Devon Bore, Paritutu S.D. Analyst, F. T. Seelye.

(2) Diopsidic augite, see Hutton, 1943, p. 354, Table I, column A. Total includes NiO, 0.04, V_2O_3, 0.045, SrO, 0.006.

(3) Augite from dacite pumice, Komagataké, Japan, S. Kozu, 1934.

(4) Augite from hypersthene olivine gabbro, Kangerdlugssuaq, East Greenland, Wager and Deer, 1939, p. 77, Table VII, column Ia.

Machatschki (1929) has proposed the general formula: XY $(Si, Al)_2$ $(O, OH, F)_6$ for monoclinic pyroxenes, in which X = Na, Ca, K, and Y = Mg, Fe, Mn, Al, Ti. Therefore on the basis of six (O, OH, F) atoms to the unit cell the clinopyroxene analysis has been recalculated (Table IV).

TABLE IV.—CALCULATION OF FORMULA OF CLINOPYROXENE.

	Wt. %	No. of Metal Atoms on Basis of 6 (O, OH, F).		
SiO_2	49.90	1.886		2.00
			0.114	
Al_2O_3	3.18	0.140	0.026	
TiO_2	0.92	0.027		
Fe_2O_3	3.10	0.084		
FeO	7.65	0.240		
MgO	11.77	0.662		2.00
MnO	0.58	0.018		
CaO	21.87	0.885		
Na_2O	0.71	0.050		
K_2O	0.15	0.009		

Formula: (Mg, Fe″, Fe‴, Ca, Mn, K, Na, Ti, Al)$_2$ [(Si, Al)$_2$ O$_6$].

It will be observed that most of the aluminium is replacing silicon, while all of the titanium is required to bring up the Y group to 2 demanded by the structure.

The pyroxene is low in sesquioxides generally, and additional analyses of diopsidic types are presented for comparison. It is difficult to explain adequately the green colour that is developed, but possibly it is due to the FeO and Na_2O, with the mineral showing a tendency towards aegirine-augite; the optical properties appear to have been little affected by the presence of a small amount of the aegirine molecule.

If Al_2O_3 Fe_2O_3, TiO_2, and alkalies are neglected as has been suggested (Wager and Deer, 1939, Hess, 1941), the analysis may be recalculated in terms of the minals Wo, En, and Fs; this gives the following result: Wo 51, En 33, and Fs 16. Now if the values of 2 V and $\gamma \wedge c$ for this pyroxene are plotted on Wager and Deer's diagram (1939, p. 80) the composition would appear to be Wo 45, En 30, and Fs 25 (weight per cent.). In this case, therefore, the determination of chemical composition using 2 V and the angle $\gamma \wedge c$ is quite unreliable. Undoubtedly the minor constituents, particularly Fe_2O_3 and TiO_2, must have a very considerable effect on the optical properties. However, it is most necessary that the angle $\gamma \wedge c$ should be accurately measured, and for this the method of Nemoto (1938) is used when possible. According to Hess's classification the pyroxene belongs to the diopside-hedenbergite group of pyroxenes for the ratio (molecular per cent.) Wo: En + Fs = 1:1·02 and the pyroxene falls in the restricted field of the salite.

In the New Plymouth rocks, diopside has usually resulted from magmatic resorption of hornblende and concomitantly with this reaction there has been precipitation of magnetite. A study of ratios MgO :FeO in the analysed amphibole (Table I, anal. 1), and diopside clearly shows the later formed pyroxene to be the less ferriferous mineral, the magnetite representing the excess over that required in the reaction.

LEONHARDITE.

A fibrous zeolite which the writer has interpreted as leonhardite, is an important constituent of the Devon Well porphyrite (P. 9330–9333). It occurs in an irregular, patchy manner, replacing andesine, and frequently the plagioclase is entirely replaced by the zeolite. Rarely it forms radiate aggregates when it appears to have been

one of the last minerals to crystallize. The mineral was carefully separated from the rock by the usual centrifuge methods and the analysis was made by F. T. Seelye. In Table V the New Zealand mineral is compared with seven others obtained from the literature and a study of this table will reveal some distinctive features in analysis No. 1. The mineral has a slightly higher percentage of silica than the other minerals, but this is offset by a rather low figure for alumina. The figure for combined water is below that in any of the other analyses, and this property appears to be reflected in the refractive indices.

TABLE V.—ANALYSES OF LEONHARDITE AND LAUMONTITE.

	1	2	3	4	5	6	7	8
SiO_2	54.10	52.13	50.64	50.82	50.96	52.34	52.24	53.04
Al_2O_3	20.44	23.04	21.86	20.06	21.60	22.27	22.14	22.94
Fe_2O_3	1.70	0.20	—	2.18	0.03	—	—	—
TiO_2	0.11	nil	—	—	—	—	—	—
MgO	0.45	trace	0.74	0.02	—	—	trace	—
CaO	8.65	11.85	12.18	12.14	11.27	10.83	10.55	9.67
Na_2O	2.60	0.14 (Na₂O + K₂O)	0.42	0.31	0.32	—	—	—
K_2O	0.55		1.34	0.22	0.18	—	0.43	—
MnO	0.05	nil	—	—	—	—	—	—
H_2O+	9.32	12.64	12.01	14.87 (H_2O+ and H_2O-)	16.04 (H_2O+ and H_2O-)	14.06 (H_2O+ and H_2O-)	15.14 (H_2O+ and H_2O-)	14.64 (H_2O+ and H_2O-)
H_2O-	2.13	—	1.58					
	100.10	100.00	100.77	99.97	100.40	99.50	100.81	100.31
α	1.502*	1.508	1.505	1.504	—	1.511	—	—
β	1.512	—	—	1.514	—	1.518	—	—
γ	1.514	1.524	1.513	1.516	—	1.522	—	—
$\gamma-\alpha$	0.012	0.016	0.008	0.012	—	0.011	—	—
2 V	35–38°†	—	—	25–35°	—	—	—	—
Sp. Gr.	2.38‡	2.2–2.3	2.23	—	2.283	—	—	—

(1) Leonhardite from porphyrite P. 9332, Devon Well, Paritutu S.D. Analyst: F. T. Seelye.
(2) Laumontite from vughs in Enoggera granite. Whitehouse, 1937, p. 541. Analyst: Queensland Government analyst.
(3) Laumontite, Southern Oregon. McClellan, 1926. Analyst: V. E. Shannon.
(4) Laumontite from North Table Mountain, Golden, Colorado. Henderson and Glass, 1933.
(5) Laumontite from Nova Scotia. Walker and Parsons, 1922.
(6) Laumontite from Hawaiian Islands. Dunham, 1933.
(7) Laumontite from granodiorite at Zsidóvár. Takats, 1936.
(8) Laumontite (= hypostilbite) from Snizort, Skye. Heddle, 1901, p. 91, analysis No. 5. Analyst: Scott.

The analysis has been recalculated on the basis of the formula $(Ca, Na)_7\ Al_{12}\ (Al, Si)_2\ Si_{26}\ O_{80}.\ 25H_2O$, proposed by Berman (1937, p. 357) for laumontite, FeO, Fe_2O_3, etc., having been neglected in this calculation.

TABLE VI.—RECALCULATION OF ANALYSIS OF LEONHARDITE.

	Wt. %	Metal Atoms on Basis of 80 Oxygens.		
SiO_2	54.10	27.65	26.00	26.00
			1.65	1.98
			0.33	
Al_2O_3	20.44	12.33	12.00	12.00
CaO	8.65	4.73		7.86
Na_2O	2.60	2.76		
K_2O	0.55	0.37		
H_2O	11.45	19.52		19.52

Formula: $(Ca, Na, K)_{7.86}\ Al_{12}\ (Al, Si)_{1.98}Si_{26}\ O_{80}.\ 19.52\ H_2O$.

It will be noted that the theoretical figures are not obtained for the (Na, K, Ca), group and for total H_2O, but otherwise the formula fits reasonably well, and since the ratio $Al_2O_3 : (CaO+Na_2O+K_2O) = 0{\cdot}98$ and following this $O : (Al+Si) = 1{\cdot}95$, the mineral is a true zeolite. There appears to be a considerable substitution of Ca by Na and K, as was found by Hey (1937) for the thomsonite group. Berman (1937, p. 374) states that considerable variation is usually shown by these ions in laumontite, and that a range from an almost pure Ca minal to a member with a ratio Ca : Na = 5 : 2 may occur. The New Zealand mineral, therefore, appears to be a more sodic, less calcic member of the laumontite group than has hitherto been described.

In his discussion of this mineral group Winchell (1933, p. 392) states that laumontite very readily loses about one-eighth of its water, when it is called caporcianite, leonhardite or β-leonhardite. Walker and Parsons (1922) state that on exposure to air one molecule of water is quickly lost. In the New Zealand mineral, however, the amount of water, even when total water is employed, is approximately one-fifth less than that usually recorded for laumontite, and on this basis alone the use of the term leonhardite seems justified. The refractive indices appear to be too low compared with those usually quoted for laumontite but are comparable with the data given for laumontite No. 3 in Table V, and by Larsen (in Winchell, 1933, p. 391). It is of interest to note that Larsen and Berman (1934, p. 153) later classify this latter zeolite with α 1·506, β 1·512 and γ 1·517, as leonhardite. In addition the maximum extinction angle $Z \wedge c$ for the New Zealand zeolite is·40°, almost equal to the figure of 44° determined by Larsen and Berman (*loc. cit.*) for a leonhardite. Finally Walker and Parsons (1922) have shown that, due to the loss of water from laumontite, there is fundamental change in optical orientation resulting in an increase in the extinction angle on prismatic cleavage plates, to 40° which is much greater than the maximum extinction angle on the clinopinacoid of fresh laumontite.

Chabazite.

A mineral, tentatively determined as chabazite, is an important accessory constituent of a curious hybrid-type of rock (P. 9340) outcropping on Mataora Island. It occurs in idiomorphic to subidiomorphic, elongated, and sometimes triangular grains; the latter are generally simply twinned and appear as if they are sectors of pseudo-hexagonal crystals. The refractive index is approximately 1·486, and the birefringence about 0·006. The optic axial angle does not appear to exceed 20–25° and in some cases the mineral is uniaxial or very nearly so; a positive sign is general. If the author is correct in identifying this mineral as chabazite, then, according to data given by Winchell (1933, p. 385), it seems to be a fully hydrated calcium-chabazite.

Anhydrite.

The anhydrous form of calcium sulphate is a minor accessory constituent in the porphyrite where it occurs closely associated with other secondary products such as calcite, chlorite and zeolites. Anhydrite usually crystallizes in subidiomorphic, rarely idiomorphic grains up to 1·0 mm. in length. Two perfect cleavages, and one

slightly less perfect, and polysynthetic twinning on (101) are characteristically developed. The optic-axial angle determined for four grains was found to be 36° in every case while the optic sign was positive. The axial angle in this case appears to be lower than that usually recorded for anhydrite, for Winchell (1933, p. 98), Larsen and Berman (1934, p. 107), and Rogers and Kerr (1942, p. 216) quote a figure of 42°. Refractive indices determined by the immersion method gave:—

$$\alpha = 1{\cdot}573 \ (1{\cdot}570)^*$$
$$\beta = 1{\cdot}579 \ (1{\cdot}576)$$
$$\gamma = 1{\cdot}618 \ (1{\cdot}614)$$
$$\gamma - \alpha = 0{\cdot}045 \ (0{\cdot}044)$$

In the literature available to the writer, no mention was found of the occurrence of anhydrite in igneous rocks. Gypsum, on the other hand is not uncommon, particularly in hydrothermally altered andesite pyroclastics and flows (Larsson, 1940, pp. 317–385). This occurrence of anhydrite in association with very hydrous minerals such as zeolites is of considerable interest, and in order to advance any explanation for its occurrence, the phase relationship of the different calcium sulphates requires to be understood. Recently Posnjak (1938) has published the results of his study of the system $CaSO_4$–H_2O in which he states that " owing to the fact that the only dissociation pressure curve that gypsum has, does not reach the value of the vapour pressure of its saturated solution until the temperature of 97° ± 1° is attained, gypsum in contact with its solutions between 42 and 97·5° represents a true metastable system, which in the absence of anhydrite nuclei may persist indefinitely." Posnjak has shown by experiment that gypsum in contact with its solution at 75° remains unchanged after long periods; but, if anhydrite is added to this, then the solid phase consists only of anhydrite. From this summary, therefore, we may assume that the late hydrothermal solutions from which anhydrite crystallized must have been at a temperature at least in excess of 42° C., and that early development of embryonic crystals of β $CaSO_4$ or anhydrite has prohibited crystallization of any gypsum.

CRISTOBALITE.

Crisobalite has been recognised in most of the rocks of Paritutu, Mataora Island, and Ngataierua Point. It occurs in irregularly shaped, colourless " pools " up to 0·3 mm. in diameter but usually averaging 0·1 mm., or rarely as strings of subidiomorphic grains through the plagioclase phenocrysts. In the " pools " or clear areas of cristobalite no definite idiomorphism of the mineral is apparent but in some cases they bear some similarity in appearance to the bead-like crystals figured by Greig, Merwin, and Shepherd (1933, p. 66, fig. 1). The refractive index is not noticeably distinct from that of a paraffin oil mixture of 1.485. The birefringence is very low and in very thin portions of the slide it can be detected only by the use of a mica plate; further, multiple twinning is not developed. From the point of view of refractive index alone, the writer believes the determination as cristobalite is satisfactory.

* Figures in brackets from Winchell (1933, p. 98).

The occurrence of cristobalite in patches and vesicle-like aggregates points to a late period of crystallization and, therefore, a rather low temperature for deposition. The presence of cristobalite, the high-temperature modification of silica, in circumstances that indicate a low temperature of crystallization, is not uncommon. Foshag (1926, p. 16) has described its occurrence lining cavities in the obsidians of Obsidian Cliff, and it has been recognised as the mineral attached to the walls of lithophysae and other cavities in rhyolitic rocks from Southwestern Yellowstone Park by Howard (1939); the latter writer also observed megascopic crystals of cristobalite along joint cracks where the rocks were appreciably altered, probably by siliceous solutions. In their investigation of the San Juan lavas Larsen *et al* (1936) recognised the importance of cristobalite (and tridymite); they found it to be the most common silica mineral in the gas cavities of basalts, but less common in the andesitic types of lavas, while its presence in the groundmass of rhyolites was confirmed by *X*-ray powder photographs (Hurlbut, 1936). Again Fenner (1938, pp. 45–47) has observed the crystallization of cristobalite from fumarolic exhalations on the shattered andesites of Falling Mountain near Katmai Pass, Alaska, while Rosicky (1928) records crystals of cristobalite, together with other minerals, occurring in cavities of andesites in southern Silesia. Kuno's (1933) investigation of the silica minerals in the groundmass of a series of basic igneous volcanic rocks from north Idu District, Central Japan, has shown that cristobalite is commonly present; and he is also of the opinion that some "tridymite" of earlier writers is in reality cristobalite. A study of a series of intermediate volcanic rocks from the Keli region in the Middle Caucasus by Ustiev (1934, p. 164) has shown the existence of dacites containing both tridymite and cristobalite, about 5% of these constituents being present, though up to 10% has been recorded in some cases. The author is of the opinion that these minerals have originated by solution of the glassy mesostasis by magmatic gases at moderately low temperatures.

The experiments of Greig, Merwin, and Shepherd (1933) have made it very clear how readily cristobalite may crystallize as a metastable phase at relatively low temperatures, and very low pressures provided water is present. The presence of cristobalite in vesicles and cavities in lavas is itself a clear indication of a relatively low temperature of crystallization, while Fenner's evidence from Falling Mountain is most significant. In view of these data it is believed that the crystallization of cristobalite in the Paritutu dacites has been facilitated by the late aqueous solutions which were apparently present in abundance as indicated by the occurrence of zeolites and deuteric carbonates.

PETROLOGY OF THE PARITUTU-DEVON BORE ROCKS.

Devon Bore Rocks.

Macroscopically these rocks are light coloured to pale grey, with plentiful phenocrystic feldspar and hornblende, the latter in prisms up to 10 mm. in length. In the 31 feet or so of core the igneous material is fairly homogeneous; although, adjacent to the igneous-sedimentary contact, a slight increase in the amount of dark con-

stituents is apparent (Pl. 15, fig. 1). In most specimens there is a pronounced orientation of the amphibole crystals within a plane normal to the axis of the bore, and there is also a rather marked parallelism within that plane.

A study of a thin section of the rock from the deepest part of the well (P. 9331, 9332) shows that very considerable hydrothermal alteration has occurred, principally in the plagioclase (Pl. 15; fig. 2A). The rocks are all holocrystalline with a very finely crystalline groundmass. Plagioclase occurs in two generations, and although the feldspar is so replaced by zeolite that little else but irregular relicts remain, pronounced zonary structure, and twinning on Carlsbad and albite laws were observed. The alteration products and inclusions are often themselves zonally arranged. The composition is, in the main, about An_{30}–An_{33} with nuclei as basic as An_{42} and peripheral zones sometimes as sodic as An_{27}. Hornblende is the most important coloured constituent present and occurs briefly as phenocrysts (Pl. 15; fig. 2B); the optical properties of this mineral have been fully dealt with in the previous section on mineralogy. Crystals commonly show repeated twinning, and zoning was observed in some cases. Where this latter structure is present a pale nuclear zone is commonly separated from a pale periphery by an intervening narrow dark band. Inclusions are common, usually pyrite, magnetite, apatite, anhydrite, or zeolitized feldspar, but swarms of colourless needle-like bodies oriented parallel to the vertical crystallographic axis were also noted; these needles have a refractive index lower than the amphibole, while the birefringence is about 0·010. Diopsidic augite is subordinate to amphibole, and occurs in crystals, rarely as large as 1·5 mm. Only very rarely did the hornblende and pyroxene show a reaction relation to one another. Leonhardite has almost completely replaced the phenocrystic and groundmass feldspar and in addition has crystallized as nests and irregular veinlets. A most unusual feature is seen in the occurrence of anhydrite to the extent of about 1½–2% (Pl. 15, fig. 2A). This constituent is sometimes closely associated with other secondary products such as calcite, zeolites, and chlorite. The latter mineral usually crystallizes in tuft-like aggregates commonly enclosed in pools of leonhardite, and in addition to its close association with other secondary minerals, it appears to be developing from the amphibole.

Iron ores include allotriomorphic grains of magnetite and cubes of pyrite. Calcite, and granules and prismatic crystals of apatite up to 0·2 mm. in length are minor but important constituents; not infrequently apatite has crystallized at the same time as the anhydrite with which it may be closely associated. Sphene is present as aggregates of allotriomorphic grains, sometimes clearly derived from iron-ore, while again it has been noted as distinct wedge-shaped crystals embedded in calcite or anhydrite.

The rocks between the level of P. 9331 and 9332 at 9408 feet and P. 9326 at the igneous-sedimentary rock contact at 9388 feet vary but little. The most noticeable feature is the gradual change from a finely crystalline groundmass to a microcrystalline one adjacent to the actual contact, and as a result the rocks close to the contact appear to be more strongly porphyritic. In addition, some minor changes in the accessory constituents may be noted. The percentage

of anhydrite in rocks adjacent to the contact seems to be less important than in the deeper rocks, whereas pyrite is much more plentiful in the former (P. 9326–9327). Quartz, often in sharply idiomorphic crystals showing development of hexagonal pyramids and prisms, and not exceeding 5%, occurs in some sections (P. 9326–9328; 9333); it has clearly crystallized late in the sequence as it is associated with the secondary minerals. Augite, which was free from alteration in P. 9331, occurs in the upper zones only as irregular relicts embedded in green serpentinous products. Calcite is important in some sections (P. 9333), and rarely glomeroporphyritic clots of hornblende, magnetite, and pyrite were noted (P. 9333).

The microcrystalline mesostasis appears to be composed chiefly of finely divided chlorite, zeolite and leucoxene; possibly some feldspar and quartz are present.

The sedimentary rock lying immediately above the porphyrite is an indurated gritty mudstone or argillite consisting of angular fragments of quartz and feldspar never exceeding 0·1 mm. in diameter. The somewhat gritty bands alternate with bands of very fine grain-size (clay-grade) that have less than 5% of angular fragments of quartz and feldspars. The feldspars can barely be recognised as such on account of almost complete alteration to sericite, kaolin or clinozoisite. Lamellar twinning may sometimes be observed in remnants of relatively unaltered plagioclase. Quartz is usually clear and fairly free from the mechanical effects of pressure, although occasional grains show undulatory extinction. Other relict grains observed include biotite, now much chloritized, and muscovite. Pools of chlorite and serpentinous material probably indicate completely altered ferromagnesian constituents and large grains of clinozoisite and iron-poor epidotes may be either allogenetic or represent the anorthite molecule of the altered plagioclase in the mudstone itself. The fine-grained base of groundmass is composed of an intimate mixture of kaolin, quartz, sericite, chlorite, clinozoisite, dusty iron-ore or carbonaceous material and leucoxene; plagioclase is almost certain to be present, although any specific identification was not possible.

Cutting across the sedimentary rocks close to the intrusive contact are narrow planes, more or less horizontal but slightly oblique to the bedding. At first glance the effect is as if the sediment were current bedded. In thin section, however, the planes are represented by strings or lines of dark material that appears most probably to consist of hydrated iron or manganese oxides or both. It is suggested that these planes are shear-surfaces formed either by submarine slumping of the wet sediments or by pressure produced by intrusion of the porphyrite magma from below.

The chief effect of the intrusive porphyrite has been to weld the argillite slightly, for drilling has proved that as the porphyrite body is approached the apparently homogeneous sediment becomes much harder.

The Igneous-Sedimentary Rock Contact.

It is most surprising that the porphyrite magma has effected only very minor thermal changes in the argillite, causing merely some induration and perhaps slight bleaching of the sediment. At the actual contact of the two rocks no re-crystallization of the sedimentary

material has occurred, although islands and tongues of sediment are seen within the porphyrite itself. The slight variations from the normal porphyrite are shown in Pl. 15, fig. 3, and these variations extend over a distance of only about 3–4 mm. This contact may be considered to consist of three narrow zones in addition to the argillite material. First extending down from the actual contact for approximately 1·0 mm. is a zone of almost crypto-crystalline material similar to the porphyrite mesostasis except that it is fairly free from phenocrysts, is not so altered, and surrounds numerous unaltered islands of argillite. This grades imperceptibly down into the next zone of approximately the same width, which is more comparable with the normal porphyrite from the bottom of the bore. Following this is a narrow band of rather abnormal composition with abundant phenocrystic hornblende and idiomorphic to subidiomorphic pyrite crystals. From this zone downwards only minor changes in the porphyrite have been observed, and these have been mentioned previously.

THE ROCKS OF PARITUTU.

The rocks outcropping on and around Paritutu are all rather light grey, strongly porphyritic, and with large, prominent, tabular phenocrysts of plagioclase and acicular crystals of hornblende.

In thin section, the porphyritic nature of the rock is emphasised because the feldspar and amphibole crystals are set in a hyalopilitic groundmass of microlites of feldspar and augite with a small residuum of colourless or rarely pale brown glass. In some cases (P. 9336) the phenocrysts increase in number to such an extent that the groundmass is more correctly termed mesostasis. Crystalline material usually predominates over glass, though in rare cases (P. 6658) glass is predominant.

Plagioclase occurs in idiomorphic tabulae up to 5·0 mm. in length and these are usually flattened parallel to 010. In the groundmass they occur as minute microlites or at the most narrow laths. Zoning is most pronounced and twinning on albite, pericline, and combined Carlsbad-albite laws is usual. The composition of the plagioclase does not vary notably from rock to rock, but owing to zoning the composition in individual crystals varies from An_{34}–An_{50}; usually the composition averages about An_{45}. A rhythmic type of zoning is often developed in the plagioclase phenocrysts, but particulars of this have been discussed earlier in this paper. Inclusions of glass and portions of groundmass are common, and these may be of irregular shape or definitely globular; the arrangement is either haphazard or strictly zonal, but more commonly the latter, although in most cases the marginal zone or periphery of the phenocrystic plagioclase is entirely free of any inclusions. Although inclusions of hornblende, apatite, and glass occur in most of the andesine phenocrysts of a particular rock, some phenocrysts in the same rock may be completely devoid of inclusions; again in some rocks all of the phenocrystic plagioclase is entirely free of inclusions. It is difficult to understand the manner by which some plagioclase crystals in crystallizing during the intratelluric period incorporated some of the magmatic liquid while others did not.

Amphibole, the most important mafic constituent in these rocks, usually occurs in prismatic crystals up to 4·0 mm. in length. It is a strongly pleochroic type of hornblende with colour varying from greenish-brown through yellowish-brown to a warmer brown tint; the latter, however, nowhere approaches the colour of lamprobolite (Rogers, 1940, p. 828). Slight zoning is evident in most cases, and is usually shown by the development of a green peripheral zone surrounding a brown or greenish-brown central portion (Text-fig. 4B); in some cases curious greenish-brown blotches occur in brown crystals. A poor hour-glass structure was noted in some cases. Twinning is uncommon, but if developed, is parallel to the orthopinacoid. Resorption has occurred to a different degree in different specimens, varying from merely a narrow border zone surrounding the hornblende to examples where there has been complete reaction with the magma involving removal of the amphibole. The products of resorption appear to be plagioclase, diopside, and magnetite; as the resorption becomes important, the amount of clinopyroxene in the rock increases considerably.

Usually the products of resorption are closely associated with one another or with the partially resorbed amphibole, but this relationship is not quite so clear in those rocks where the resorption of amphibole is complete or nearly so. In all rocks where resorption is important the groundmass has a minimum amount of glass, but in one glassy type (P. 6658) resorption of the amphibole, or of biotite which is present in this case, has not occurred (Text-fig. 4B). Larsen and Irving's work (1937) on somewhat similar rocks from the San Juan region, Colorado, has clearly shown comparable features in the resorption of hornblende, and they point out that the absence of resorption in rocks with a glassy groundmass clearly indicates that much of the resorption took place after the lavas had been erupted. The evidence of the Paritutu rocks certainly seems to support this contention. Clinopyroxene is not an abundant constituent and occurs chiefly in close association with resorbed hornblende although to a minor extent dispersed throughout the rock as minute granules or prismatic crystals. Its occurrence as phenocrysts up to 2·0 mm. in length, is rare, and only in a glassy type (P. 6658) are they at all well developed (Text-fig. 4B). In all cases, the pyroxene is a diopsidic type with very faint green tint and in some examples extremely delicate pleochroism. Slight zoning was noticed in a few cases and lamellar twinning is uncommon. Only rarely was any alteration noticeable, but in one case (P. 9341) a pale green negative chlorite occurring in the form of minute spherules appeared to have developed from the pyroxene. Biotite is an unusual constituent and was observed in only one rock, a glassy type from the cliffs on the north side of Paritutu, where it constitutes less than 5% of the rock. Here the mica occurs in plates of slightly rounded outline up to 2·0 mm. in diameter. Resorption has never proceeded beyond the development of a narrow peripheral zone of fine iron oxide dust and a colourless prismatic or granular mineral, probably pyroxene (Text-fig. 4B). Resorption is not so extensive as that seen in the San Juan lavas described by Larsen and others (1937, p. 900).

Pleochroism is intense, varying from very pale straw yellow (X) to a very deep rusty-brown (Z).

Cristobalite was recognised in several of these rocks—e.g., P. 9334–9336, both in the groundmass, where it occurs as minute grains, and in what appear to have been steam or fluid cavities; in the latter case the grains rarely exceed 0·6 mm. in diameter. The grains are colourless and irregular and lack the twinning so characteristic of cristobalite. The birefringence is very faint and refractive index determinations exclude the possibility of the mineral being tridymite or opal. Although cristobalite usually crystallises in the vesicles of lavas, it does not seem to be so common as a constituent of the groundmass or mesostasis, but recently, however, Hurlbut (1936) has proved by X-ray methods the existence of cristobalite in the groundmass and as intergrowths with the feldspar of spherulites in some rhyolitic rocks.

The accessory minerals in this group of rocks are apatite, magnetite, and zircon. The apatite generally forms stout idiomorphic hexagonal prisms; not uncommonly the apatite crystals have a central smoky coloured zone, just sensibly pleochroic in some cases. Zircon is rare and was noted in only one case (P. 9341). Iron-ore occurs in rather ragged irregular grains, less commonly in sub-rectangular crystals that rarely exceed 1·5 mm. in diameter. Finely granular iron-ore occurs throughout the groundmass and magnetite dust is important locally in association with clinopyroxene surrounding resorbed amphibole. Microchemical tests on the magnetite dust have shown a rather low percentage of titanium, possibly not in excess of 1½–2%.

On account of the amount of visible cristobalite present in a number of these rocks, it seems more appropriate to classify them as dacites. In one specimen (P. 9341), however, with no visible quartz or cristobalite in thin section the norm calculation shows 14·75% quartz. Therefore all of the rocks of the Paritutu group are considered dacites.

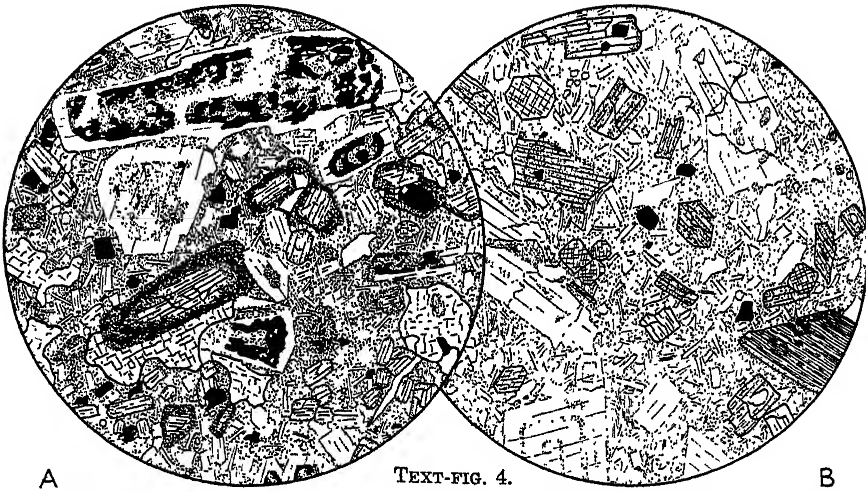
At the north-west extremity of Ngataierua Point several specimens were collected that differ somewhat from the Paritutu group, although, of course, very distinctly related thereto. In the hand specimen they are similar to the Paritutu group but contain rather more dark minerals. Microscopically they are also similar but differ in the following points:—(1) Phenocrysts of plagioclase are not so abundant. (2) Hornblende is far less resorbed than in the previous group, the amphibole phenocrysts being surrounded by only narrow zones of finely granular magnetite and a very minor augite. (3) Augite is rare throughout the rocks.

THE HYBRID ROCKS OF MATAORA ISLAND (P. 9339, 9342).

These rocks are darker in colour than the Paritutu types and not so coarsely porphyritic.

The base is made up of microlites of feldspar, much fine granular augite, magnetite, cristobalite, and a residuum of almost colourless glass.

The plagioclase occurs in coarse idiomorphic phenocrysts, commonly twinned on several laws, and zoned. The phenocrysts show a curious type of alteration in which most of the centres of the crystals



A TEXT-FIG. 4. B

(A) Basified dacite (P. 9339) from the east side of Mataora Island showing zonally altered bytownite phenocrysts, heavily resorbed hornblende, and clear areas of cristobalite. X 26.

(B) Glassy dacite (P. 6658) from the seaward side of Paritutu. Phenocrysts of andesine are clear and almost unaltered; hornblende, slightly zoned, and biotite, show only faint resorption effects. X 26.

are replaced by a microcrystalline aggregate of pale yellow material with low birefringence and irregular granules of what are believed to be oxidised siderite (Text-fig. 4A). In many cases, very narrow peripheral zones of the plagioclase crystals are water-clear and devoid of any inclusions (Text-fig. 4A), and an intermediate clouded zone is seen in some crystals; others are completely free from any inclusions at all. It is considered that much of the pale yellow, poorly birefringent material is glass, perhaps in some cases somewhat devitrified. The cloudy intermediate zone, on the other hand, consists of feldspar, magnetite, shreds of glass and diopsidic pyroxene; other granules are present but the identity of these is not certain. In the main, zoning in the plagioclase is not so pronounced as in the feldspar of previous groups, although the oscillatory types of zoning were also observed here. A few crystals have been noted with corroded margins but lacking zoning.

The unusual feature of these rocks is the composition of the plagioclase, which is in no case less calcic than An_{73}, and examples with up to 80% of the anorthite molecule, particularly in the core of the phenocrysts, have been recorded.

Both hornblende and pyroxene occur as large phenocrysts. The amphibole has more pronounced brown colour in these rocks with a pleochroism that follows the scheme:—

α = yellow.
β = brown.
γ = deep olive brown.

Resorption has occurred extensively, producing broad peripheral zones of finely granular magnetite, and augite (Text-fig. 4A). In

some instances where resorption has proceeded nearly to completion, a type of sieve-structure is developed in addition to alteration around the peripheral zone; this consists of the skeletal remains of amphibole phenocrysts sieved with rarely twinned, new formed plagioclase, diopsidic pyroxene, and magnetite. Complete resorption of the amphibole has occurred in some instances. Phenocrystic clinopyroxene, in crystals up to 2·0 mm. in length, is a common constituent. Except for its abundance and phenocrystic character, the diopsidic augite is similar to that in the previous groups of rocks. Accessory constituents are similar to those in the dacites—viz., apatite, cristobalite, and iron ores; some celadonic material and ferriferous calcite is also present.

On the west side of Mataora Island an extremely altered type (P. 9340) has been observed. This is a crushed feldspathic rock with the plagioclase averaging about An_{75}. Amphibole and pyroxene are absent, but very abundant carbonate with the γ refractive index varying from 1·658–1·667 is present. Microchemical tests indicate considerable iron in the ferrous state but no manganese or magnesium. From Winchell's table (1933, p. 70) it seems that this carbonate must contain up to approximately 7–10% $FeCO_3$ in solid solution. The refractive index varies considerably and there is marked zonary banding in the ferriferous calcite; this is particularly noticeable when oxidation of the carbonate takes place, the resultant limonite being precipitated in a zonary fashion. A zeolite tentatively referred to as fully hydrated calcium chabazite is an important minor constituent of these hydrothermally altered hybrid rocks. It is intimately associated with carbonate, and the idiomorphic form of the mineral suggests a late date for the period of crystallization.

Scraps of intensely pleochroic biotite are scattered throughout the rock: these are occasionally much altered to limonite but show no sign of resorption or chloritization. Rare patches of micaceous quartzo-feldspathic schist with intensely pleochroic biotite were also observed; these patches are interpreted as xenoliths of pelitic sediment that have been caught up and recrystallized by hot andesitic magma in the deeper zones of the magma chamber where temperatures have been higher than appear to have existed in the porphyrite.

Cristobalite, coarse crystals of apatite (up to 0·3 mm. in diameter) and iron-ore are accessory constituents.

PETROCHEMICAL DISCUSSION.

As stated earlier, it is held that the andesites and dacites are genetically connected with the sill of porphyrite that was located in the Devon No. 1 Bore at a depth of 9388 feet. It is the writer's contention that magma from the chamber now occupied by this porphyrite was injected upwards along a series of tension cracks or planes caused by a doming-up of the magma chamber. A study of analyses and norms A, B, and C in Table VII makes it clear that except for slight increase in the amount of SiO_2, represented mineralogically as cristobalite in B and C, these rocks are chemically similar. In addition, in Table VII the chemical compositions of the New Plymouth rocks are compared with those of similar types. In the case of the porphyrite (analysis A) it will be noted that whereas soda is fairly high, potash is very low; an important amount of water occurs, the latter

being due almost entirely to the presence of a considerable amount of leonhardite. The occurrence of anhydrite is, of course, reflected in the small amount of SO_3 recorded in the analysis. It should be noted that although nearly 3% of quartz occurs in the norm, this was not recognised as a modal constituent.

The analyses B and C seem to place these rocks definitely in the dacite group; thin section study of P. 9341 (analysis B), however, did not reveal any quartz or cristobalite so that the 14.75% of quartz in the norm probably represents cristobalite in the groundmass. These two analyses (B and C) are closely alike, and for comparison, analyses F, G, and H have been included.

The hybrid rocks of Mataora Island, however, fall into a slightly different category. It has been observed that these rocks, though comparable in most respects with the andesites and dacites, contain an extremely basic plagioclase, An_{73}–An_{80}, and in addition some specimens contain an important amount of xenolithic material. An analysis of one of these types (analysis D) has been made, and it will be noted that CaO is higher and Na_2O lower than in any of the associated rocks.

The occurrence of large phenocrysts of bytownite, sometimes partly resorbed and set in an environment not dissimilar to that of the associated dacites, suggests that they did not crystallize from magmas in which they are now found. In dealing with a very similar problem, Larsen *et al* (1938, pp. 252–256) come to the conclusion that although some of the crystals may have originated by floating from a lower, or settling from a higher layer of magma of different composition, it is more probable that they are the result either of the mixing of two partly crystallized magmas or of reaction between andesitic magma and country rocks. Unfortunately the present author has little definite evidence to offer on this issue; but it must be pointed out that although some reaction has occurred between andesite magma and the mudstone country rock, as shown by the recrystallization of xenoliths as quartz-biotite aggregates, this reaction could not bring about precipitation of very basic plagioclase. It seems more probable that the bytownite xenocrysts have originated by the straining away of early formed phenocrysts from a basic magma, and subsequent incorporation of these in the dacite or andesitic magma. However, it should be noted that in this district there are no known igneous rocks more basic than andesites.

TABLE VIII.

Depth in Feet.	H_2O	K_2O	Na_2O
8755–8767	1.34	3.09	2.55
9021–9037	2.96	3.05	2.32
9383	0.72*	—	—
9385	0.65*	—	—
9387 (1 foot above sill)	0.72	2.17	2.72

All of the igneous rocks of the Paritutu area, and particularly those on Mataora Island, have been affected by late magmatic solutions and vapours. These agents are believed, as has been shown earlier, to have brought about the distribution and crystallization of cristobalite. To this must be added the extensive zeolitization of the feldspars that has occurred in the sill rocks and in the hybrid or

* Analyses by C. Osborne Hutton, remainder by F. T. Seelye.

An aerial view of Paritutu (centre), and Mataora, Pararaki, and Tamatea Islands. Ngataierua Point is to the left of Paritutu.

FIG. 1.
A section of the core obtained at 9,388 feet in No. 1, Devon Well, showing the junction of the porphyrite (left) and mudstone (right). ¾ natural size.

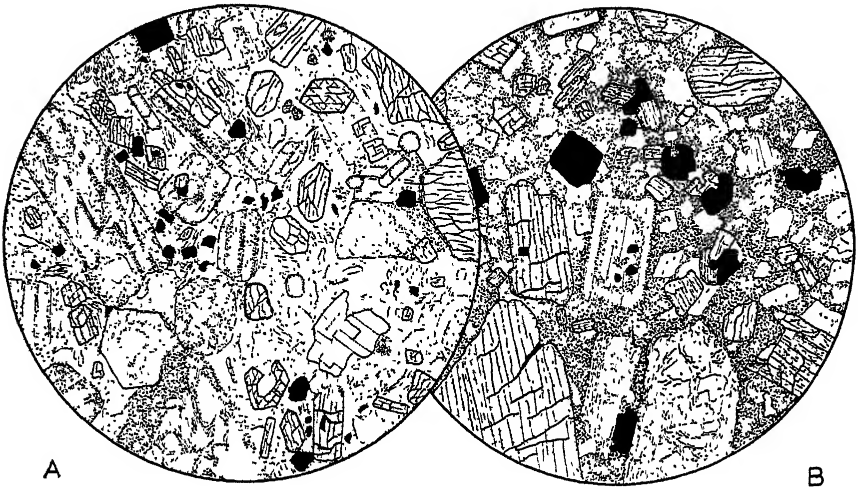
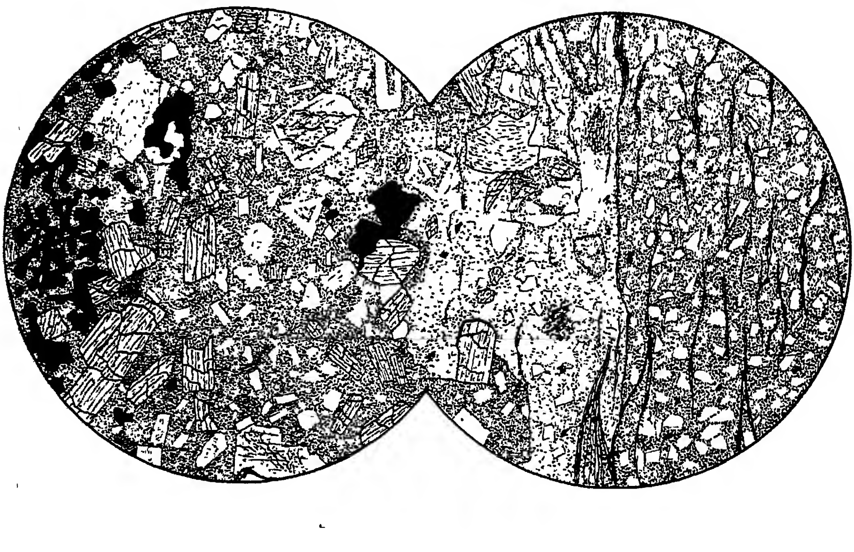


FIG. 2A.
Porphyrite (P. 9331) showing zeolitized plagioclase, with hornblende and anhydrite set in a base of zeolite and altered feldspar. X 26.

FIG. 2B.
Porphyrite (P. 9327) one inch below the mudstone-porphyrite contact, showing phenocrystic hornblende, and zoned and zeolitized plagioclase. X 26.



basified rocks of Mataora Island. The abundance of sideritic calcite in the latter rocks is also believed to be due to hydrothermal solutions. It is possible that the source of some of this water lies in the thick series of fine-grained sedimentary rocks that has been invaded by porphyritic or dioritic magma.

Determinations of hygroscopic water in several specimens of the fine-grained mudstones taken from the Devon Bore, indicated a relatively " dry zone " close to the sill contact as shown in Table VIII. However, in view of the very slight contact effects produced by the sill, a low temperature for this magma seems necessary.

On account of the abundance of soda in the porphyrite, soda metasomatism of the surrounding mudstones was suspected. In view of this, alkali determinations were made in three cases by Mr. Seelye, but, as the figures in Table VIII show, nothing significant appears to have occurred; the apparent decrease in K_2O in the sediments adjacent to the sill cannot be correlated with any absorption of K_2O by the porphyrite, which is abnormally low in this constituent.

AGE OF THE IGNEOUS ROCKS.

Clarke (1912, p. 21) has grouped the dacites and andesites of Paritutu and the Sugarloaf Islands together with the neighbouring tuffs and agglomerates that cover most of Paritutu and adjoining survey districts, as the Pouakai Series; further he has suggested that there was a strong resemblance between the Pouakai rocks and the andesitic agglomerates, breccias, etc. of Miocene age in the Whangaroa Subdivision. Marshall (1907, pp. 375–376) on the other hand, believed that the Pouakai rocks were older than the basaltic types of Auckland yet younger than the rhyolites of the Central Plateau of the North Island.

The Devon No. 1 bore, after penetrating about 280 feet of tuffs, passed down through a thick series chiefly of fine sandstones and siltstones ranging downwards in age from Waitotaran or Urenian to Mahoenui. It is into sediments belonging to the latter group that the porphyrite laccolith or sill has been injected, and, if the author's cone-sheet theory is correct, the dacite sheets or dykes have penetrated through the entire sequence. The sedimentary rocks from the bore are particularly poor in tuffaceous or other igneous material, and only at about the 6,500 feet mark is there a very poor development of slightly tuffaceous mudstones. Thus here is clear evidence that the volcanicity at Paritutu did not contribute any debris to these Taranakian sediments, and therefore the age of the massive igneous rocks of the New Plymouth area appears to be post-Waitotaran, or at least post-Urenuian; that is, early Pliocene or latest Miocene. The presence of water-sorted tuffs and rounded, worn boulders in the igneous debris adjacent to Paritutu supports Clarke's belief that there was a considerable time interval between the deposition of the agglomerates and tuffs, and the emplacement of the dacites. It is held by the present writer that the Pouakai tuffs post-date the period of cone-sheet development, although it is possible that surface manifestations of these intrusions may have given rise to a minor amount of tuffs, etc. Thus the Pouakai tuffs proper, in the vicinity of Paritutu, were deposited in a shallow sea from which rose concentric rings of islands,

these being the remnants of the cone-sheets brought into relief by erosion of the soft Waitotaran sediment during post-Waitotaran, but pre-Pouakai times. The source of the Pouakai tuffs is probably to be looked for in the Pouakai and Kaitaki Ranges.

TABLE VII.—CHEMICAL COMPOSITION AND AFFINITIES OF THE IGNEOUS ROCKS OF THE PARITUTU AREA.

	A	B	C	D	E	F	G	H
SiO_2	53.65	60.21	60.65	51.49	53.34	60.71	62.48	64.27
Al_2O_3	17.83	18.74	19.55	16.61	15.95	18.53	18.07	16.87
Fe_2O_3	2.65	2.65	2.39	5.35	2.43	2.02	2.61	3.13
FeO	3.73	1.20	1.16	3.46	4.93	2.16	1.97	2.01
MgO	2.99	1.69	1.16	3.69	5.23	1.26	1.34	1.85
CaO	7.09	6.26	7.40	8.04	7.96	5.66	4.67	4.63
Na_2O	5.51	4.06	4.27	3.42	5.42	4.82	4.69	3.97
K_2O	0.90	1.91	1.98	1.21	0.63	1.93	2.16	1.68
H_2O+	2.88	1.35	0.87	1.98	2.75	2.45	0.52	1.20
H_2O-	0.37	0.86		2.41	0.09	—	0.12	
CO_2	0.37	trace	—	1.04	—	—	nt. fd.	—
TiO_2	0.73	0.58	0.35	0.81	1.21	0.77	0.60	0.38
P_2O_5	0.26	0.39	—	0.25	0.63	0.22	0.28	0.08
ZrO_2	nt. fd.	nt. fd.	—	—	—	—	nt. fd.	—
V_2O_3	0.02	0.015	—	0.035	—	—	—	—
S	0.29	0.03	—	0.08	—	trace	0.03	—
SO_3	0.62	—	—	—	—	—	—	—
MnO	0.16	0.09	0.08	0.22	—	trace	0.17	0.06
NiO	nt. fd.	nt. fd.	—	—	—	—	—	—
Cr_2O_3	trace?	trace	—	0.015	—	—	—	—
BaO	0.13	0.21	—	0.09	—	—	0.09	—
SrO	0.07	0.065	—	0.05	—	trace	—	—
Cl	0.01	trace	—	0.11	—	trace	—	—
	100.26	100.31	99.86	100.36	100.57	100.53	†99.80	*100.20
Less O for Cl				0.02				
				100.34				
Sp. Gr.	2.65	2.65	—	2.67	2.84	2.702	—	—

† The summation in Washington and in original publication is incorrect.
* Additional constituents 0.07%.

Normative composition:

Q	2.85	14.75	12.48	9.10	—	13.14	15.06
or	5.34	11.30	11.68	7.18	3.89	11.12	12.79
ab	42.57	34.34	36.15	27.68	45.59	40.35	39.82
an	23.39	27.26	28.36	27.04	17.24	23.63	21.68
th	1.10	—	—	0.13	—	—	—
di	6.31	0.93	6.26	3.83	14.95	1.94	—
wo	—	—	0.12	—	—	—	—
hy	8.45	3.77	—	8.45	3.42	2.30	4.19
ol	—	—	—	—	5.41	—	—
mt	3.31	2.48	3.02	7.66	3.48	2.55	3.71
il	1.39	1.11	0.61	1.54	2.28	2.89	1.22
ap	0.60	0.94	—	0.60	1.34	—	0.67
pr	0.55	—	—	0.09	—	—	—
hm	—	0.94	0.48	—	—	0.32	—
(cc)	0.84	—	—	2.36	—	—	—
hl	—	—	—	0.18	—	—	—

A. Porphyrite (P. 9331) from 9408 feet Devon No. 1 bore, New Plymouth, Paritutu S.D. Analyst: F. T. Seelye.
B. Dacite (P. 9341) 2 chains south of Paritutu, Paritutu S.D. Analyst: F. T. Seelye.
C. Dacite, seaward face of Paritutu. Analyst: J. S. Maclaurin (*Bull. N.Z. Geol. Surv.* no. xiv, p. 23, analysis 11).
D. Hybrid rock or basified-dacite (P. 9339), Mataora Island, Paritutu S.D. Analyst: F. T. Seelye.
E. Kersantite, Washington, 1917, p. 526, analysis 14.
F. Diorite porphyrite, Washington, 1917, p. 260, analysis 66.

In their work in the Mokau area, Henderson and Ongley (1923, pp. 55–56) drew attention to the marked resemblance between the rocks of Whareorino§ and Paritutu; presumably the dacites of Pehimatea (P. 3093, 3096, 3099) should be included in this comparison also. The age of these lavas is not definitely known, as no contact with Tertiary beds has been observed; however, Henderson and Ongley infer that an upper Miocene age is probable on account of the widespread occurrence of andesitic agglomerates, and crystal tuffs in the Mohakatino Series, in particular in the lowermost beds. The apparent absence of any Tertiary beds beneath the Whareorino lavas is curious, and suggests that the greywacke block on which the lavas rest had been a rigid elevated block for some considerable time. However, the relation of these igneous rocks to the Mohakatino Series appears to be quite uncertain, and there is no evidence to show whether the greywackes were always devoid of a Tertiary covering or whether such rocks were stripped off before the period of volcanicity at Whareorino. The age of the Whareorino volcanics then can only be fixed between wide limits; they are pre-Mohakatino but post-Jurassic or post-Taranakian. If the rocks are comparable with those at New Plymouth then a Pliocene or perhaps Pleistocene age is more likely.

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Vol. 74, Part 2, pp. 154–164; 5 Plates, 16–20.

Notes on the Anatomy of *Diadromus (Thyraeella) collaris Grav.* (Ichneumonidae, Hymenoptera).

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Introduction.

The Ichneumon, *Diadromus collaris* was introduced into New Zealand from Western Europe during the summer and autumn of 1937-38, as a pupal parasite of the diamond-back moth, *Plutella maculipennis.* It was successfully established in New Zealand, and has become a very active agent in the control of *Plutella.* The extreme ease with which this parasite can be bred and handled in the laboratory, its hardiness, the short duration of its life-cycle, and the longevity of the adults, all make it an ideal subject for study, both morphologically and ecologically.

The lack of structural information on the Ichneumonidae is surprising, especially when we consider the taxonomic difficulties of the group, which cannot be overcome except by thorough anatomical knowledge. The high degree of specialisation of function, and the parallel diversity of anatomical structure, give us a most absorbing and in the realm of insect physiology, a most instructive field for research. The following notes describe the structure of a typical Ichneumon, and have little claim to originality. However, it is hoped that the information contained will be of value in helping to form the basis of a better understanding of the structure and function of a very interesting and complicated group of insects.

The Thorax (Plate 16, Figs. 1 and 2).

(a) The Prothorax.

The prothorax consists of a pronotum (pr.) and a prosternum (prs.). The propleura have become fused with the lateral cervicals (ltc.). The pronotum is a large sclerite, narrow in front, but curving around and back to form two large triangular plates, extending around the edge of the episternum to a point just above the coxae (cx.) of the prothoracic legs. The prosternum is a small trapezoid plate lying between the posterior ends of the lateral cervicals, and obscured by the bulbous procoxae.

(b) The Mesothorax.

Dorsally, the mesothorax consists of a prescutum (pres.) and scutum (sc.) together forming the most conspicuous part of the thorax, and the scutellum (scl.) and parascutellum (pscl.). The scutum and prescutum form a large, rounded, somewhat trilobed plate which anteriorly meets the transverse arch of the pronotum.

The anterior lobe is the prescutum, and the lateral lobes, separated from it by the parapsidal sutures, are the parapsides. It is at the base of these parapsides that the tegulae and wing attachments are located. Separated from the scutum by the scutellar fovea (scv.), is the scutellum and parascutellum. The scutellum curves forward laterally to embrace the posterior portion of the scutum. It is a comparatively narrow, arched sclerite, and in *Diadromus,* is not distinctly divided from the parascutellum, which consists of two triangular plates extending to the bases of the wings, and between them.

The mesosternal and mesopleural elements are fused to form the largest sclerite in the thorax. Below, this plate bridges the gap between the fore and mid legs, and is divided by ridges to a definite mesosternum (meso.), episternum (eps.), and anterior angled prepectus (prpt.). The pleural suture (pls.) is represented by a strong ridge, leading up to the processes of the hind wing. The upper portion of this pleural plate is the mesepisternum (mps.), while the lower and more posterior portion is the mesepimeron (mpm.). Between the prepectus and the mesepisternum is the prepectal carina (ptc.). In *D. collaris,* the line of demarkation between the mesosternum and the mesepimeron is also somewhat carinate.

(c) The Metathorax.

In the metathorax of *Diadromus,* the prescutum, scutum, scutellum and postscutellum, are not clearly defined. The prescutum is hidden by, and merges with, the mesopostscutellar region, and is not seen on casual observation. The scutum merges from the prescutum, and is seen as a narrow, arched, transverse band. The metascutellum (mts.) is fused with this element, and together they form the major portion of the metanotum. The metapostscutellum (mtps.) is not in any way differentiated. The fusion of the anepisternum (anep.) and anepimeron (apm.) is complete, and these fused plates curve back below the first abdominal spiracle to unite with the large plate formed by the fusion of the katepisternum (kts.) and katepimeron (ktm.).

THE PROPODIUM (Plate 16, Figs. 1 and 2).

The propodium is morphologically closely related to the thorax, and on casual observation might easily be mistaken for the metanotum. It consists of the first abdominal tergite. The corresponding pleural and sternal elements have become completely atrophied. Dorsally, it slopes away from the metanotum to its horseshoe-shaped posterior extremity, where it articulates with the petiole. The propodium is divided by carinae into three median and five lateral areas. The median dorsal areas are the basareola (bas.) in front, the hexagonal areola (ar.) in the centre, and the petiolarea (pet.) extending back to the petiolar articulation. Laterally, the two anterior and uppermost areas are the external or first lateral area (lat.1) in front, and the area dentipara, external median, or second lateral (lat.2) area behind it, extending back from the second median area or areola. The small antero-lateral area in front of the spiracle is the spiracular area (spa.), and the long, narrow portion behind the spiracle is divided into the lateral, middle pleural, or second pleural (mp.) area in front and the internal, middle apical, or third lateral (lat.3) area behind.

Wing-coupling (Plate 16, Figs. 3, 4, and 5).

The wing-coupling apparatus is on the typical hymenopterous plan. The trailing edge of the fore-wing is bent over in two areas to form folds (fd.), and into these folds fit hamuli (hm.) which project backward from the leading edge of the hind wing. The folds on the fore-wing occur towards each end of the hyaline post-anal area, and are slightly stiffened by extra chitinisation. The hamuli of the hind wing are placed in two corresponding sets. The proximal set consists of only one hamulus in the form of a very stout bristle with a hooked, bifid tip. Just proximal to this hamulus are several large, straight bristles which apparently serve to keep the folded portion of the fore-wing firmly pressed against the hamulus proper. In this proximal coupling the fore-wing is not closely applied to the hind-wing, the hamulus projecting straight and vertical before it forks, and the wings being held apart by the set of bristles previously mentioned.

The distal coupling is attained by the association of a fold in the fore-wing with a series of five stout hamuli on the hind-wing. These distal hamuli, unlike the proximal ones, curve backwards and outwards from their bases. The most proximal member of this set is the shortest and has a simplex apex. The remainder increase in length progressively and show increased development of the bifid tip from the innermost member outwards. The wing membrane in the proximity of these hamuli bears only short papillate hairs, indicating that the overlap of the fore-wing is in this region in close apposition to the dorsal surface of the hind-wing.

The Articulation of the Wings (Plate 16, Figs. 6 and 7).

The wing articulates with the thorax by means of a complicated set of sclerites or pteralia set in a membranous area. These sclerites are very delicate, and it is only with great difficulty that their true relationships can be determined in the smaller members of the Hymenoptera. The arrangement is rather more complex in the fore-wing than in the hind-wing, but both possess essentially similar elements.

The articulation of the fore-wing is by means of a basicostal (bc.) (humeral) plate on which the costa (C), radius (R), media (M) and cubitus (Cu) articulate, a group of four axillary sclerites (ax 1 – ax 4), and a median plate (mpl.). The anal vein (A) articulates on the third axillary and median plates. The basicostar is a very large, heavy sclerite, which lies between the tegula (tg.) and the four anterior veins of the wing. In *Diadromus* it is separated from the costal, radial, and medial bases by a comparatively large oval sclerite, while the cubital articulates with an elongate sclerite interposed between it and the oval element mentioned above. Between this "basicubital" (bcl.) plate and the lower distal prolongation of the basicostal, lies the flattened median plate, which is subdivided, with a narrow subsidiary portion forming an articulation between the median proper and the upper base of the anal vein. Proximally, the basicostal plate articulates with the large and complex first axillary plate. The second axillary articulates anteriorly with a distal arm of the first axillary, and posteriorly with the base of the third axillary,

which lies at an acute angle with it. Anteriorly and distally, the third axillary articulates with the lower base of the anal vein. The fourth axillary is a very small plate lying embedded in the membrane posterior to the third axillary.

In the hind-wing, the basicostal appears to be fused with the base of the anterior wing vein complex. The median is a large, thin plate articulating between the anal vein and the base of the median vein. It is more or less triangular in outline, with its acute apex forming its anterior articulation. The first axillary is three-branched, with its anterior and longest prolongation articulating with the basicostal, and its distal prolongation articulating with the base of the second axillary. The second axillary is more or less triangular, with its sides somewhat inflexed, and its base placed distally. The anterior angle articulates with the subcosta, and the lower portion articulates with both the first axillary and the elongate third axillary. The third axillary articulates proximally with both the first and second axillaries, and distally with the base of the anal vein. As in the fore-wing, the fourth axillary is very small, and lies in the membrane posterior to the main complex.

MOUTH-PARTS (Plate 17, Fig. 8).

The labrum (lm.) is small, and attached to the under surface of the clypeus (clp.) near its centre. It is armed anteriorly with sensory hairs, and posteriorly with comb-like bristled plates. Below it is a membranous epipharynx (ephy.).

The mandibles (md.) are fairly slender, curved, and terminate in two blunt teeth. The outer tooth is somewhat the longer of the two, and the bifid nature of the tip is continued basally in the form of a groove. The articulation of the mandibles is by means of a pair of ball-and-socket joints. In the dorsal articulation, the socket is on the mandible, while the condyle is on the pleurostoma. The ventral articulation consists of a condyle on the mandible itself, and a deep socket in the base of the gena. There are two rows of long sensory hairs on the inner face of each mandible, two large curved hairs on the outer side of the outer tooth, and several similar hairs just above the condyle. There is also a row of plocoid sensilla on the inner side of the mandible, and three or four stout hairs above the lower condyle.

The maxillae are well developed, and well supplied with sensory hairs. The cardo (cd.) is not strongly chitinised, and is devoid of sensory apparatus. The upper end is broad and somewhat flattened, tapering to a " waist " behind. Behind this constriction it bifurcates to form inner and outer prolongations to which muscles are attached. The stipes (st.) is considerably larger than the cardo, and articulates with it on a broadened base. Distally, the stipes articulates on its outer side with the maxillary palp (mx. plp.), and on its inner side with the galea and lacinia. Running diagonally from the inner side at the base, to the outer side at the socket of the palp, is a distinct carina. The stipes has only a few sensory hairs, nearly all being placed on the outer basal portion. The maxillary palp is five-jointed, and richly supplied with sensory hairs. The basal segment is elongate and slender, and articulates at an angle with the second segment, which is more or less straight in outline on its outer side, but much

swollen on its inner side. The third segment is slightly longer and less bulbous, while the last two segments are slender and about the same length as the first segment. Sensory hairs and setae are present on the distal portion of the first segment, and occur densely over the entire surface of the other segments. The galea (ga.) is flattened and spathulate. Around its outer edge are setal sensilla, while over its inner edge and part of the surface, are very fine hairs. The lacinia (lc.) is much smaller, and fits into the curved base of the galea. It is entirely covered with fine hairs.

The labial assemblage is comparatively small, the entire length of the prementum including the ligula being only slightly greater than that of the stipes. The submentum (smt.) is membranous, and carries no sensory hairs. The prementum (prmt.) is pyriform, heavily chitinised, and supplied with scattered sensory hairs and placoid sensilla. It is very strongly inflexed at the margins. At its distal end the glossae (gl.) and paraglossae (pgl.) articulate, and just below these, the labial palps (lb. plp.) arise from definite palpigers (plg.). These palps are four-jointed structures with a similar supply of sensilla to those present on the maxillary palps. In the labial palps, the middle two segments are squat and pyriform. The glossa is a large flat bilobed structure with numerous parallel grooves and ridges in its surface. It contains several types of sensilla, including the symmetrically placed, almost straight chaetae projecting anteriorly, and an anterior row of basiconic sensilla. The apical margin is in the form of a comb, with straight, close bristles all of uniform length. Paraglossae occur basally at each side of the glossa, and these pad-like structures are covered dorsally with short, stout, curved sensilla. The papillate hypopharynx at the base of the glossa marks the opening of the salivery duct.

Alimentary System (Plates 17 and 18).

The mouth opens into the pharynx (ph.) which lies vertically above it. The pharynx (Fig. 10) is lined with thick chitin and is shaped more or less like a D lying with its flat side ventral. The floor of the pharynx is in the form of a chitinous plate slightly raised in the middle. The lateral angles are much folded, and very flexible, allowing the roof and floor to be pressed together by muscular contraction. Strong muscles are inserted in this chitinous lining both dorsally and ventrally. Dorsally these muscles are mainly longitudinal, while ventrally there are strong transverse bands.

The epithelium of the fore-gut is homologous with the hypodermis, and in the vicinity of the pharynx is fairly typical of it.

In the oesophagus proper (oe.) which extends from the pharynx back to the posterior end of the petiole, the layers take on a more typical arrangement (Fig. 11). The cuticle is very thin, and raised to form innumerable small lobules and papillae. These contain prolongations of the underlying epithelium, the cells of which are more or less cubical. These cells have medium-sized nuclei, and do not appear to be markedly glandular or secretory in function. Outside this epithelium is a basement membrane, and outside this again are scattered longitudinal muscle fibres overlain by circular fibres, both bearing fine striations.

The crop (cr.) appears to be structurally a mere enlargement of the oesophagous, and consists of precisely the same elements. Towards its posterior end, however, near the proventriculus (pvent.), it becomes remarkably thin-walled, and muscle development is greatly reduced.

The proventriculus or gizzard (pvent.) in *Diadromus* is very highly differentiated from the rest of the fore-gut, and projects into the mid-gut in the form of a definite oesophageal invagination (Fig. 15). In the proventriculus proper the muscle layers are greatly increased. The circular layer is particularly strong in its development, and forms a distinct sphincter surrounding the entire organ. From about the middle of the proventriculus, the epithelium increases in development until towards the posterior end the cells are definitely columnar, and form an internal circular ridge, falling away behind to the large columnar cells of the oesophageal invagination. The invagination is covered with epithelial cells on both sides, and may be likened to a rubber tube, the edge of which has been turned back on itself. However, it contains no muscle layers, and the inter-epithelial space appears to be in the form of a blood sinus (bls.). It is interesting to note that the proventriculus is lined outside with a definite columnar epithelium, but whether this represents the extent of the folding back of the epithelium of the invagination, or whether it is mesodermal in origin, is difficult to determine.

At the junction of the oesophageal invagination and the mid-gut, a definite peritrophic groove (pgr.) is present, and it is from this point that the extremely delicate peritrophic membrane (pmb.) is formed. This membrane lines the entire mid-gut, and apparently disintegrates from its posterior extremity.

The cells of the mid-gut epithelium are large and columnar. They are highly vacuolate basally, and often very finely vacuolate distally. The nuclei are very large, and usually contain two or three large aggregates of chromatin material. Distally, the cells appear to be bordered by a vertically striated layer in which lies the peritrophic membrane. Groups of regenerative cells (rgr.) appear at irregular intervals at the bases of the epithelium, and these produce new epithelial cells.

The muscle layers are not obviously striated, and are only weakly developed. In the mid-gut, the muscles are in the opposite position from the fore- and hind-gut, having the longitudinal fibres outermost.

The mid-gut extends to the base of the fourth post-petiolar segment, and here it narrows to a short tube from which arise the twelve malpighian tubules (mlp).

The hind-gut consists of the same layers as are present in the fore-gut, but developed tó a very different degree. In *Diadromus,* the ileum (il.) and colon (cln.) are small and nearly all the proctodaeumal region of the gut is taken up by the large pyriform rectum (rect.). The ileum (Fig. 9) and colon are not differentiated, and there is no apparent difference in the elements constituting their wall. They are lined throughout with cuticle, and beneath this lies a cubical epithelium. The muscle layers (consisting of an inner circular layer, and an outer longitudinal layer) are weakly developed, and not visibly striated. The nuclei of the epithelial cells are small.

The rectum (Fig. 16) is very large, and narrows to the anus posteriorly. It is lined with cubical epithelium, and has, besides the typical muscle layers, a secondary inner circular layer of simple, unstriated fibres. The outer circular layer is strongly developed and striated. The rectal glands (Fig. 14), although six in number, are not arranged in such a manner as to give the rectum any semblance of a hexagonal cross section as is often the case. They are roughly arranged in two sets of three, one set behind, and alternating with the anterior set.

These rectal glands consist of large, tapering columnar cells, overlaid as is the entire hind-gut, with a chitinous cuticle. Basally these cells contain very large vacuoles, which contain a loose granular reticulum. The entire cytoplasm is reticulate except at the internal margin where it is very dense, and contains several vacuoles. The nuclei are very large, and contain no large karyosomes. Beneath each group of columnar cells is a basal " pad " (bp.) of intersticial cells.

Posteriorly, the chitinous lining of the rectum is very greatly thickened. There is a rectal valve (rect. v.) which appears actually to consist of two valves with a chamber between. The posterior portion of the rectum, or anus proper, which lies behind the anterior valve, is without longitudinal muscle fibres, but is surrounded by very strongly developed circular muscles.

According to Wigglesworth (1939), the hind-gut, and particularly the rectal glands, have a water-absorbing function, and cause the removal of water from the faecal matter, with a corresponding replenishing of body-moisture.

Reproductive System (Plates 19 and 20).

The reproductive system of parasitic Hymenoptera is of great interest on account of its modifications to conform with highly specialised means of oviposition. The ovipositor is a remarkable example of natural adaptation, and merits close study as regards both basic structure, and mechanical function. The male genitalia, although lacking the obvious functional interest of the female apparatus, are interesting from a taxonomic point of view and have been suggested as a systematic characteristic (Snodgrass 1941, Peck 1937, and Crampton 1919). In addition, the internal organs merit study, particularly as regards the female, in which conditions necessary for production of mature ova are so often dependent on the presence of the host as a pre-ovipositional food source.

In the present account, the internal and external structures are described in some detail, and a brief account of an important physiological factor governing the development of the gonads of the female is given.

(A) External Genitalia.

(i) The Female (Figs. 17–20).

The eighth and ninth may be considered as the genital segments, since it is the tergites of these which serve to support and protect the genitalia. The last abdominal spiracle is present in the eighth segment. Although in both of these segments the tergites are not markedly modified, the sternites are greatly altered to form the

ovipositor lancets and sheaths (Fig. 18). The ninth segment is normally telescoped into the eighth, and bears the anus at its dorsal extremity. The tenth and eleventh segments are represented by two atrophied plates basal to the anal protruberance, and just above these plates are the paired anal cerci (a.c.).

Pivoted at the base of the ninth segment is the broadened, plate-like base of the first valvifer (v.f.1.). This structure articulates with the second valvifer (v.f.2) behind, and at the base of the flattened, plate-like portion, it tapers off to the thin, flexible outer portion forming the first valvula (v.1) of the ovipositor proper. The internal portion of the first valvula arises as an internal prolongation of the base of the first valvifer. These two thin rods fuse to form one of the paired first valvulae or ovipositor lancets.

The second valvifer is partly covered by the posterior margins of the ninth abdominal segment, and articulates near its base with the first valvifer. Below this, it expands to form a large, incurved plate which serves as a point of attachment for the muscles operating the genitalia during oviposition. Posteriorly, this plate bends back to form the second valvulae which fuse posteriorly to form the third section of the ovipositor proper. At its dorsal extremity, about midway between the anus and the ventral extremity of the ninth abdominal segment, the second valvifer gives rise to two lateral setose sheaths (the third valvulae) which serve to cover and protect the ovipositor lancets (valvulae).

The lancets are barbed at their tips and are secured together by paired hooks fitting into sockets (Figs. 19–20).

(ii) The Male (Figs. 21–22).

In the male, the ninth abdominal segment has both tergal and sternal elements, but has no pleurae. As in the female, the tergite has no spiracles.

Behind the ninth abdominal segment is the basal ring (br), a collar-like sclerite encircling the bases of the parameres (pm). In *Diadromus* it is not complete dorsally, and is carinate on its ventro-distal edge. The parameres are very large, broad, setose plates, with their ventro-distal edges reflexed, almost completely covering the inner genitalia. The reflected edges, together with the slightly incurved, pointed tips of the parameres, probably serve a clasping function during copulation.

The copulatory ossicles consist of a large basal volsella (vo), and a small apical segment, the sagitta (sa). The volsella itself is prolonged into an incurved horn distally, and this opposes the incurved and slightly larger sagitta. The sagitta is armed with short, stout spines, while the tip of the volsella bears long bristles, and a few placoid sensillae.

Between and dorsal to the volsellae is the more or less cylindrical aedagus (ae), consisting of a pair of penis valves. In *Diadromus,* the parapenes (pa) which usually appear as supporting structures to the aedagus proper in Hymenoptera, are not differentiated from the penis valves. Distally, the margins of the penis valves are reflexed and hooked ventrally, to form a trumpet-shaped and downward-projecting opening.

(B) Internal Genitalia.

(i) The Female (Figs. 23–25).

The ovaries are paired, each consisting of four ovarioles (ov). The ovarioles run back and upwards, surrounding the gut and meeting dorsally to terminate in a common terminal filament (tf) towards the middle of the abdomen. Each ovariole is made up of an inner epithelial layer, which serves to transmit nutriment in solution to the inside of the ovariole for the nourishment of the developing ova, and an outer fibrous layer.

The ovariole in *Diadromus* is of the polytrophic type. At its distal extremity is the germarium, consisting of oogonia and undifferentiated cells which later form the nutritive groups and follicular epithelium. The oocytes become surrounded by follicular epithelial cells, and each such follicle alternates with a group of nutritive cells (nc). Each follicle is broken at its upper end by a small opening (micropile, m) through which a cytoplasmic stalk (ns) passes to the nutritive cells above. By the time the ovum is completely developed, the nutritive cells have been exhausted of all cytoplasmic content, and the follicular epithelium has given place to a thin, flexible chorion.

Below, the ovarioles end in short stalks, which unite to form paired oviducts (od) which lead by means of a broad, short vagina (vg) to the ovipositor.

About half-way between the point of junction of the paired oviducts and the base of the ovipositor, the spermatheca (spt), a thick-walled, almost spherical sac, opens through a short duct into the vagina. At its distal extremity the spermatheca receives a short duct from the biramous spermathecal gland (spgl.). Accessory glands are absent.

(ii) The Male (Figs. 26–30).

The testes are paired, ovoid bodies lying above the gut in front of the rectum. They are united anteriorly, and terminate in a common filament. Each testis consists of an outer fibrous layer (fc) in which is embedded the much-coiled vas efferens (ve), and an inner, spongy mass in which are embedded the sperm cysts. Each testis apparently consists of only one large sperm-tube.

The stages in the development of the sperms are readily traced. Below the apical cell (apc), the spermatogonia (spg) are seen in clusters in the spongy medulla. These groups are followed by follicles containing spermatocytes (spc), below which in order are the spermatids (sptd), and sperms (spm). No follicular epithelium has been observed surrounding these groups, although such epithelium may be present. The mature sperms lie in their follicles with their heads towards the opening of the vas efferens. The sperm has a head about one-third of its total length, and slightly bulbous at its middle.

The convoluted vasa efferentia appear to be without definite cell walls and definite nuclei are not apparent. The vasa defferentia (vd), however, have a definite epethial lining composed of highly granular cells with large nuclei, and are surrounded by a heavy layer of circular muscle fibres. The paired vasa defferentia run down and back, one on each side of the hind-gut, to enter paired vesiculae seminales (vs) below the rectum. Each vesicula is pyriform and

trabeculate in section. They are lined with densely granular cells with very small nuclei. Below, they taper to ducts which almost immediately unite to form a common ejaculatory duct leading direct to the aedagus. The ejaculatory duct is lined with columnar epithelium and is surrounded with a thick muscular layer of circular fibres with a few longitudinal fibres.

No accessory glands are present, but throughout the length of the ejaculatory duct runs a glandular ridge (glr) which probably serves the same function.

A FACTOR GOVERNING THE DEVELOPMENT OF THE FEMALE GONADS.

During the commencement of the study of the internal genitalia of the female, difficulty was experienced in obtaining well-developed ovaries. Females were mated, then fed on honey and pollen solution (made from " bee-bread ") for several days before dissection. Invariably under these conditions the ovaries were found to be poorly developed, with no mature ova present. On dissecting females which had been allowed to oviposit in host pupae for several days, it was found that ovaries were well developed, and contained as many as eight mature ova at one time. It was known that females were in the habit of feeding on host pupae before active oviposition, and it appears that this habit is necessary for the maturation of the ova.

Apparently the essentials of diet are obtained only from the fluid contents of the host pupa, and no foods tried could replace this natural source of nutriment. Such phenomena are not uncommon among female insects, and are probably the rule rather than the exception. Flanders (1935) mentions similar habits as regards a member of the Pteromalidae, and also quotes various other authors on the subject, while Lloyd (1940) mentions the same factor with *Diadromus.*

The influence of mating on maturation is of no importance apart from the influence on the sex ratio of the progeny. Ova develop parthenogenetically, but all the progeny are males.

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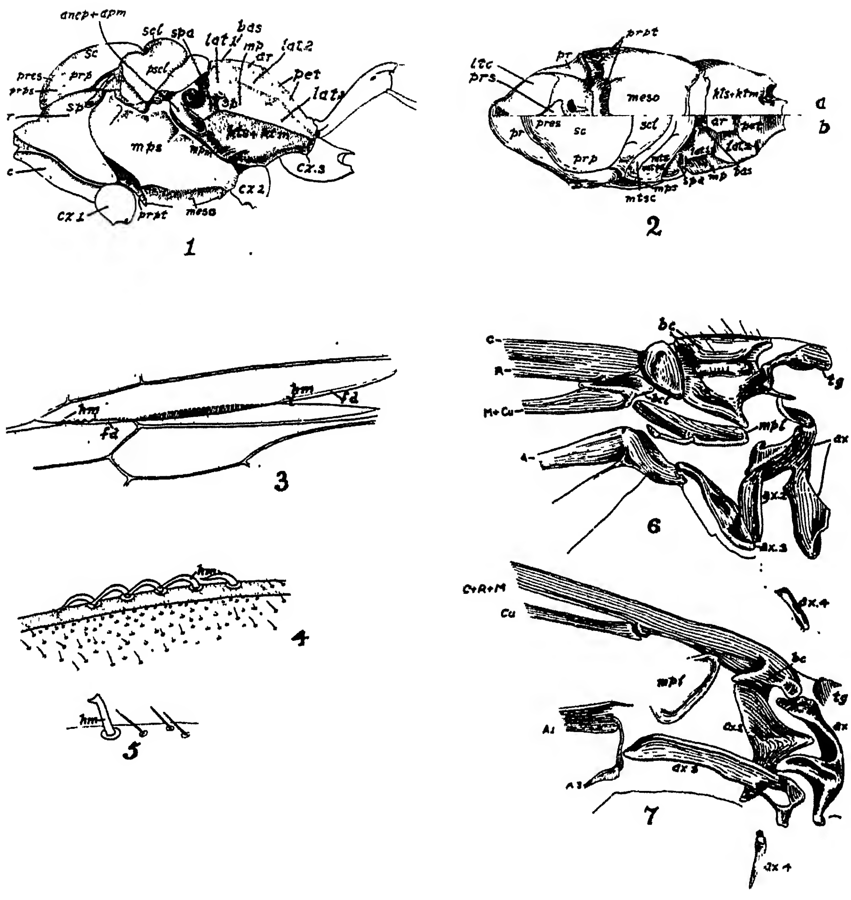
Index to Lettering of Plates.

A.—anal vein.
ac.—anal cercus.
ae.—aedagus.
anep.—anepisternum.
apc.—apical cell.
apm.—anepimeron.
ar.—areola.
ax.—axillary sclerite.
bas.—basareola.
bc.—basicostal sclerite.
bcl.—basicubital sclerite.
bls.—blood sinus.
bp.—basal pad of interstitial cells.
br.—basal ring.
C.—costa.
cd.—cardo.
cln.—colon.
clp.—clypeus.
cm.—circular muscle.
cr.—crop.
cu.—cuticle.
Cu.—Cubitus.
cx.—coxa.
ed.—ejaculatory duct.
ep.—epithelium.
ephy.—epipharynx.
eps.—episternum.
fc.—fibrous layer.
fd.—fold in wing.
fe.—follicular epithelium.
ga.—galea.
gl.—glossa.
glr.—glandular ridge.
hg.—hind-gut.
hm.—hammulus.
il.—ileum.
ktm.—katepimeron.
kts.—katepisternum.
lat.—lateral area.
lb. plp.—labial palp.
lc.—lacinia.
lm.—labrum.
lms.—longitudinal muscle.
ltc.—lateral cervical sclerite.
M.—media.
m.—micropile.
md.—mandible.
mes.—mid-gut.
meso.—mesosternum.
mlp.—malpighian tubule.
mp.—middle pleural area.
mpl.—median plate.
mpm.—mesepimeron.
mps.—mesepisternum.
mtps.—metapostscutellum.
mts.—metascutellum.
mtsc.—metascutum.
mx. plp.—maxillary palp.
nc.—nutritive cells.
ns.—nutritive stalk.
od.—oviduct.
oe.—oesophagus.
oeinv.—oesophageal invagination.
ooc.—oocyte.
ov.—ovariole.
ovm.—ovum.
pa.—parapenis.
pet.—petiolarea.
pgl.—paraglossa.
pgr.—peritrophic groove.
ph.—pharynx.
plg.—palpiger.
pls.—pleural suture.
pm.—paramere.
pmb.—peritrophic membrane.
pr.—pronotum.
pres.—prescutum.
prmt.—prementum.
prp.—parapsides.
prps.—parapsidal suture.
prpt.—prepectus.
prs.—prosternum.
pscl.—parascutellum.
ptc.—prepectal carina.
pvent.—proventriculus.
R.—radius.
rect.—rectum.
rectg.—rectal gland.
rect. v.—rectal valve.
rgr.—regenerative cells.
sa.—sagitta.
sc.—scutum.
scl.—scutellum.
scv.—scutellar fovea.
sp.—spiracle.
spa.—spiracular area.
spc.—spermatocytes.
spg.—spermatogonia.
spgl.—spermathecal gland.
spm.—sperms.
spt.—spermatheca.
sptd.—spermatids.
smt.—submentum.
st.—stipes.
tf.—terminal filament.
tg.—tegula.
tr.—trabeculae.
trm.—tranverse muscle.
ts.—testis.
v.—valvula.
vd.—vas deferens.
ve.—vas efferens.
vf.—valvifer.
vg.—vagina.
vm.—vertical muscle.
vo.—volsella.
vs.—vesicula seminalis.



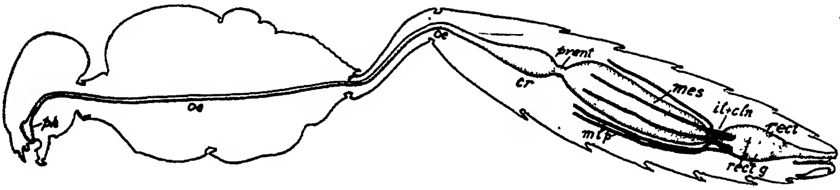
Diadromus (Thyraceliia) collaris Grav.

Fig. 1.—Thorax. Lateral.

Figs. 3, 4 and 5.—Wing-coupling apparatus.

Figs. 6 and 7.—Pteralia of fore- and hind-wings.

Fig. 2.—Thorax. (a) Ventral, (b) Dorsal.



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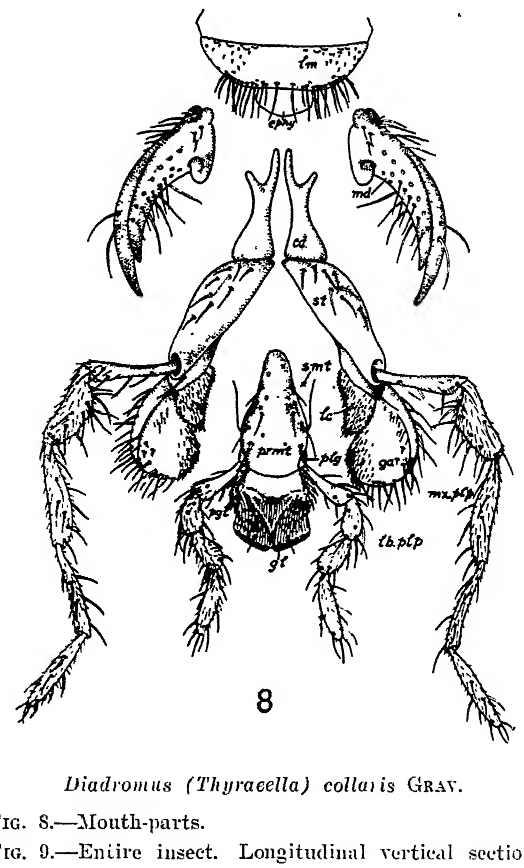

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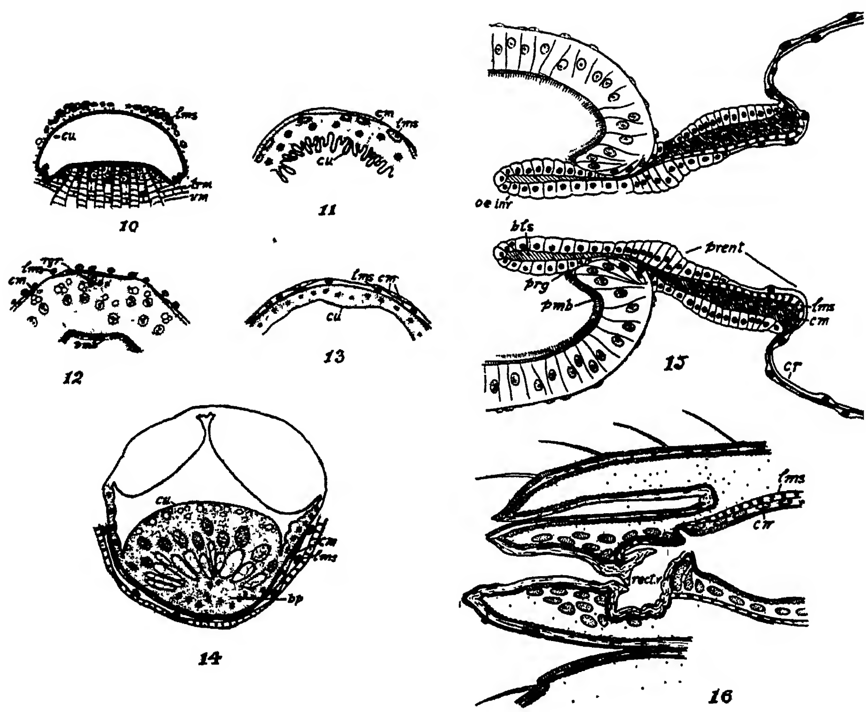
Diadromus (Thyraeella) collaris GRAV.

FIG. 8.—Mouth-parts.

FIG. 9.—Entire insect. Longitudinal vertical section.



Diadromus (Thyraeclla) collaris GRAV.

FIG. 10.—Pharynx. Transverse section.

FIG. 11.—Oesophagus. Transverse section.

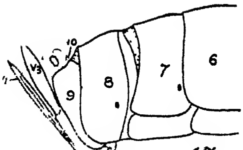
FIG. 12.—Mesenteron. Transverse section.

FIG. 13.—Ileum. Transverse section.

FIG. 14.—Rectum. Transverse section.

FIG. 15.—Proventriculus and oesophygeal invagination. Longitudinal vertical section.

FIG. 16.—Rectal valve. Longitudinal vertical section.



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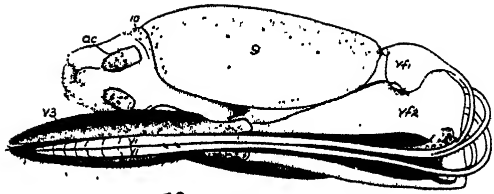

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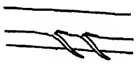

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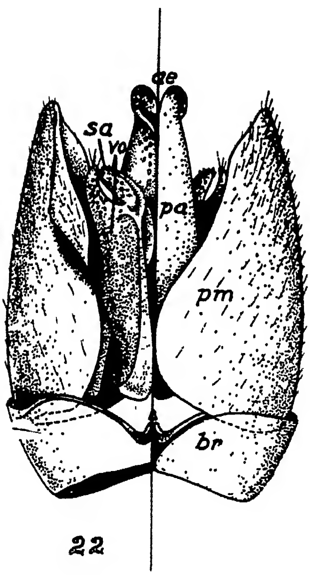

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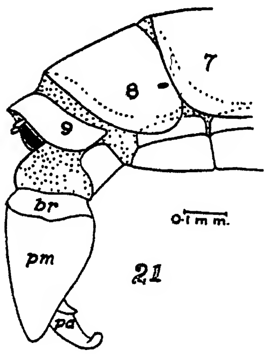

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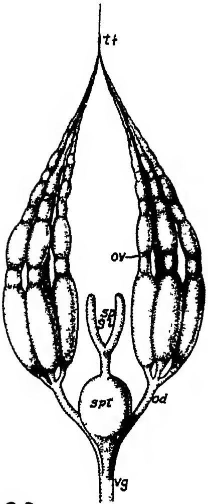
Diadromus (Thyraeella) collaris Grav.

Fig. 17.—Terminal segments and external female genitalia. Lateral.
Fig. 18.—External genitalia. Female.
Fig. 19.—Tip of ovipositor.
Fig. 20.—Coupling hooks of valvula.
Fig. 21.—Terminal segments and external male genitalia. Lateral.
Fig. 22.—External genitalia. Dorsal at right, ventral at left.



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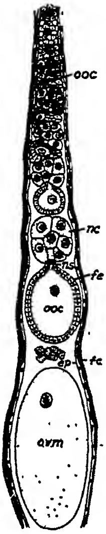

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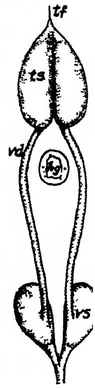

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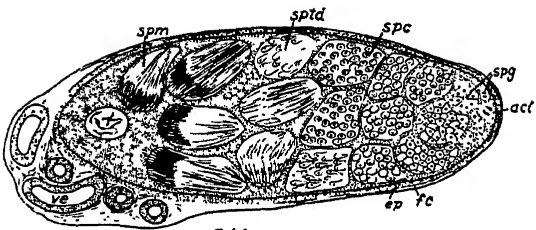

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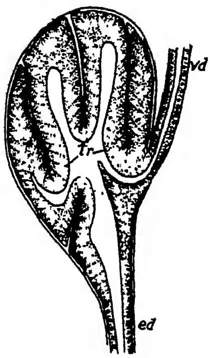

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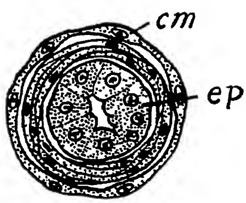

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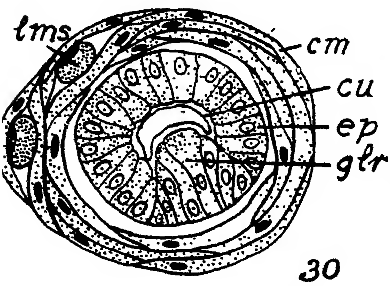

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Diadromus (Thyraeella) collaris GRAV.

FIG. 23.—Internal genitalia. Female.

FIG. 24.—Longitudinal section of ovariole.

FIG. 25.—Photomicrograph of ovum and nutritive cells in ovariole.

FIG. 26.—Internal genitalia. Male.

FIG. 27.—Longitudinal section of testis.

FIG. 28.—Longitudinal section of vesicula seminalis.

FIG. 29.—Transverse section of Vas deferens.

FIG. 30.—Transverse section of ejaculatory duct.

Vol. 74, Part 2, pp. 165–181, Plate 21 and Graph.

The Titi Wainui or Fairy Prion, *Pachyptila turtur* (Kuhl).

Part II.*

By L. E. Richdale.

Department of Zoology, University of Otago.

[*Read before the Otago Branch, September 14, 1943; received by the Editor, September 17, 1943; issued separately, September, 1944.*]

This paper is a continuation of the life story of the Titi Wainui as already narrated in a recent part of the *Transactions.* It opens with a detailed study of the chicks during their last few days ashore. Following this, appears an estimate on an important section of the community—the unemployed birds. Next are given data concerning weights and measurements of the growing chick before concluding with a section on the adults. The latter includes population statistics and a discussion of *Pachyptila turtur* on other breeding grounds.

The Departure of the Chicks.

By ascertaining the hatching and departure dates of 66 chicks I was able to work out the time they remained in the burrow. This period varied considerably from 44 to 55 days, giving an average of 49·35 days. The standard deviation is 2·81 days and the PE_m ·23. In the table below is shown the time ashore for the 66 chicks broken up into class intervals of 3 days with the number of chicks departing in each interval.

Table XI.

Time Ashore of 66 Chicks in Class Intervals of Three Days.

Class Interval in Days.	No. of Chicks.	Class Interval in Days.	No. of Chicks.
44 to 46 days	11	50 to 52 days	18
47 to 49 days	26	53 to 55 days	11

Table XII.

Amount of Down Left on 66 Chicks Whose Time Ashore is Known.

Amount of Down.	No. of Chicks.
Patches	1
Traces	7
Trace	34
1st day without down	16
2nd day without down	5
3rd day without down	1
4th day without down	1
5th day without down	0
6th day without down	1

* Part I has appeared in Vol. 74, pp. 32–48 of the *Transactions.*

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Vol. 74, Part 2, pp. 165–181, Plate 21 and Graph.

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It will be noticed from the preceding table that nearly 76 per cent of the chicks departed either with a trace of down or on the first day they were clear of all down. Generally speaking, the chicks which left early did not retain any more down than those which left late. The exception, however, was chick 9, which was the youngest to leave, being ashore only 44 days. It was the only one with patches of down when it departed. Of the five chicks which were ashore the longest period, i.e. 55 days, one had traces of down, three had a trace, and one had no down on departure. The chick which left on the 6th day after the down was gone was 54 days old.

TABLE XIII.

The Relation of the Time Ashore of 66 Chicks to the Amount of Down Left on Departure.

Days Ashore	Patches	Traces	Trace	1st day without	2nd	3rd	4th	5th	6th
44	1								
45		1	1	1					
46		1	6						
47			5	1	1				
48		1	4	2	1				
49		1	5	4		1			
50		1	4	3	1		1		
51			4	3					
52			1						
53			1	1	2				
54		1							1
55		1	3	1					
	1	7	34	16	5	1	1	0	1

The foregoing tables indicate quite plainly that the amount of down still adhering at departure may vary considerably at any given age. It was apparent, too, as the research progressed that those chicks which failed to thrive, either from lack of food or for constitutional reasons, were longer in losing their down and consequently remained ashore, on the average, for a greater period. One chick was only 45 days old when the last vestige of down had disappeared, while another took a further ten days to reach this stage.

The question now arises as to whether there is a starvation period at the end of the chick's term ashore or whether the parents continue feeding to the end. In an endeavour to solve the problem I weighed a large number of chicks night and morning during their last ten days ashore with the results shown below.

TABLE XIV.

Details of Feeding of Chicks During Last 10 Days Ashore.

Day Record Taken	10th	9th	8th	7th	6th	5th	4th	3rd	2nd	Last
No. of records ..	15	17	23	27	42	52	59	65	67	69
No. of times a chick unfed	3	5	6	7	10	18	26	32	50	59
% of times unfed	20	29.4	26.1	26	23.8	34.6	44.1	49.2	74.6	85.5
% of times unfed in class intervals of 2 days	25%		26%		29.8%		46.8%		80.1%	

TABLE XV.

Number of Days Each of 64 Chicks Stayed in Burrow After its Last Meal.

	No. of Chicks.	Percentage.
Fed on last night	10	15.6
Missed a meal on 1 night	12	18.75
Missed a meal on 2 nights	16	25
Missed a meal on 3 nights	14	21.85
Missed a meal on 4 nights	10	15.6
Missed a meal on 5 nights	1	1.55
Missed a meal on 6 nights	1	1.55

The above tables indicate that while 15.6% of the chicks are fed on the last night, the majority, or 81.2% miss from one to four meals immediately before they depart. It would appear that normally there is a short starvation period before the chicks leave, but in the main the drop in weight occurs gradually while the chick is still being fed. At least some of the Storm Petrel *(Pelagodroma marina maoriana)* and Royal Albatross *(Diomedea epomophora sandfordi)* parents return to the nest after the chicks have either undergone a short fast or have flown. With the Titi Wainui this procedure seems to be different for in no case were the palisades of sticks, placed across many of the burrows, knocked down after the chicks had gone. This seems to mean that in 84.4% of the cases the chicks were deliberately deserted by the parents, the former missing from one to six meals before leaving the island.

Some individual records of the departure of the chicks will be of interest. Chick 3bSW, weighed on only the last six days before it left, received in food 12, 1, 8, 12, 12 and 8 grams respectively. Its age on departure was 50 days and it was free of down. Chick 29 received 18 grams on the night before it left, was unfed the second last night and received 14, 7, and 8 grams respectively for the three nights prior to that. Chick 20R was fed 7, 27 and 7 grams on the last three nights. Chick 15R was given 19 and 11 grams on the last two nights and in this case I actually caught one of the parents (recognised by its ring) just outside the burrow on the night it fed 11 grams. On the departure of this chick I placed sticks across the burrow, but no adult returned. Finally, of the 10 chicks which were fed on the last night ashore, five missed a meal on the second last night at least, one was fed on the two last nights, two on the three last, while the remaining two were fed on the last six nights to my knowledge. Prior to that I had not been weighing these two.

Here are three further cases worthy of mention. Chick 1bNW, though not fed on the last two nights received the huge total of 54 grams on the third last night. Chick 49R in the last four nights received 13, 26, 31 grams and then was unfed, while chick 22 on the last seven nights was fed 33, 51, 17, 4, 0 grams, before being left unfed on the final two nights.

I have gained the impression that the chicks resemble the Storm Petrels in that they do not come to the mouth of the burrow till either the night they go or the night before. Once having emerged from the burrow they do not appear to return as seems to be the procedure with the Mutton-bird (*Puffinus griseus*) chicks. At nest

3R on February 12, 1942, the chick was observed just behind the palisade of sticks across the burrow entrance. Next morning the sticks were still intact so that the chick had not been outside nor had it been fed. That night at 11 o'clock I saw it emerging through the sticks, but when my torch shone on it the light caused it to return to the burrow.

I was fortunate in witnessing the departure of Chick 5. At 9.30 p.m. on February 16, before complete darkness, I arrived to find the chick just out of the burrow entrance. In a few minutes it was on the edge of the cliff only a few feet away and as far as I could tell took off. It may have fallen on to lower ground but a search failed to reveal it. When the chicks do decide to leave many of them issue forth long before it is properly dark and a considerable time before any adults have appeared over the island. Frequently, in this semi-darkness, they hit the tent indicating that they had been attempting to fly. Many were found clambering up to the top of the *Muehlenbeckia* round the tent and others were running at considerable speed along the paths. Moreover, they do not seem to be deterred by moonlight nights or by rough weather, behaviour which is in great contrast to that of unemployed adults.

One chick, on February 8, was found to have left the burrow. That night I discovered it sitting in the sedge not far away, having apparently spent the day somewhere else. This incident indicates, too, that all chicks do not leave the island on the night they emerge from the burrow.

Chicks without down are not easily distinguishable from the adults, but the careful observation of the ridge before the nostril and the whitish edging to the tips of the scapulars will indicate a fledgling.

TABLE XVI.

Average Weight of 62 Titi Wainui Chicks During Their Last 8 Days in the Burrow.

Day Before Leaving	Weight in gms.	Day Before Leaving	Weight in gms.
8th	148.7	4th	133.3
7th	147.8	3rd	127.5
6th	143.5	2nd	120
5th	140.5	Last	112.1

The weight on the 8th day before departure varied from 104 to 190 grams while on the last day it was from 90 to 131 grams. The 190-gram chick on the 8th last day left when weighing 131 grams, being the heaviest of all the 62 chicks. The chick weighing 104 grams on the 8th last day left at 95 grams and had throughout never been very heavy.

The above table indicates a gradual falling off in weight during the last eight days but as I mentioned previously this does not mean that feeding had ceased. Actually some of the chicks were fed on the last night in the burrow. From the table below it will be observed that nearly 70% of the chicks set out between the weights of 105 and 124·9 grams.

TABLE XVII.

Departure Weights of 65 Chicks in Class Intervals of 10 Grams.

Class Interval in Grams.	Frequency.	Percentage.
125 to 134.9	6	9.3
115 to 124.9	22	33.8
105 to 114.9	23	35.4
95 to 104.9	13	20
85 to 94.9	1	1.5

Comparing the weight of the chicks when they leave the burrow with that of the adults caught at night just as they reach the island, it will be found that the chicks, on the average, are considerably lighter. This is in marked contrast to the Storm Petrel chicks, which, at the time of leaving the burrow are heavier than the adults.

The weight of the Titi Wainui adults given in the following table may be a little higher than normal, as when caught they had in some cases not fed the chick.

TABLE XVIII.

A Comparison of the Weights of 100 Parents Caught on Whero at Night as They Arrived With 62 Chicks on the Night Each Left the Burrow.

Type of Bird	Average gms.	σ gms.	PE_m	Range gms.
Adult	131.8	13.75	.92	100 to 162
Chick	112.74	9.1	.77	90 to 131
Difference	19.06	± 1.2		

In order to ascertain the growth of the wing and its length on the day of departure a number of chicks were measured daily during the last ten days in the burrow. The results are given in the table below.

TABLE XIX.

Increase of Growth of Wing of 16 Titi Wainui Chicks During Last 10 Days in Burrow, Divided into 2-day Class Intervals.

Class Interval In Days Before Leaving	Average
10th and 9th	153.1 mm.
8th and 7th	159 mm.
6th and 5th	163.7 mm.
4th and 3rd	168.8 mm.
2nd and last	173.5 mm.

As the increase in growth from day to day was slight, owing to the liability to small errors in measurement, especially upon live birds, it was thought desirable to group the measurements into class intervals of two days. The variation in length for the last day ranges from 165 to 180 mm. The chicks measured for the purpose of the above table were different from those used for table XXIV.

In the following table the wing of 26 Titi Wainui chicks is compared with 100 parents, 50 of each sex, being taken from the breeding burrows on Whero during the 1941-42 season. From the results which indicate a significant difference, it would appear that the chicks do not attain their full wing length till they have left the burrow.

TABLE XX.

A Comparison of the Wing Measurements of 26 Titi Wainui Chicks the Day Each Left the Burrow with 100 Parents, 50 of Each Sex, Taken on Whero in the 1941-42 Season.

Type of Bird	Average	σ	PE_m	Range
	mm.	mm.		mm.
Adult	182.45	3.43	.22	170 to 191
Chick	175.11	4.18	.54	168 to 180
Difference	7.34	± .59		

On February 5, 1942, the first of the chicks under observation left its burrow. None departed on the 6th, while on the 7th, two set out. Altogether 73 left from burrows under observation while 42 were found on the surface of the ground after they had left a burrow which I had not found. On February 28, after a period of 23 days the last chick left so that the departure period is relatively short.

In the table below the departure dates are grouped into class intervals of 3 days each. Chicks under observation and chicks caught on the surface are given separately. It will be noted, too, that the bulk of the departures, i.e. 84%, occur between February 8 and 19.

TABLE XXI.

Departure Dates of 115 Titi Wainui Chicks Placed in Class Intervals of 3 Days.

Dates of Class Intervals	Chicks In Burrows Under Observation	Chicks Found On Surface After Leaving Burrows	Total
Feb. 5 to Feb. 7	3		3
Feb. 8 to Feb. 10	11	2	13
Feb. 11 to Feb. 13	13	6	19
Feb. 14 to Feb. 16	22	15	37
Feb. 17 to Feb. 19	15	13	28
Feb. 20 to Feb. 22	3	4	7
Feb. 23 to Feb. 25	5	1	6
Feb. 26 to Feb. 28	1	1	2
	73	42	115

THE EFFECT OF THE MOON.

The effect of the moon on the Titi Wainuis is interesting and will be studied from two angles. In the first instance I shall make records concerning its effect on adults feeding their young, and in the second, its influence on the behaviour of the unemployed population.

In table XXII below my time on the island in both seasons is divided into 5-day intervals, using as the key period that beginning a day before the full moon and ending four days later. This was the period yielding the maximum amount of moonlight in mid-summer. The number of times chicks could have been fed coincides with the number of times weighed each morning. The number of times fed indicates the number of times the morning weight was greater than the previous evening. Those occasions when the chicks were not fed after their last meal ashore are not counted as I consider that this lack of meals occurs whatever the state of the moon. The purpose of the table is to discover the effect of the moon when the parents are actually feeding, not when they have stopped.

TABLE XXII.

Effect of the Moon on the Feeding of Chicks. The Key 5-Day Intervals Include the Day of the Full Moon.

Class Interval 1940-41	State of Moon	No. of Times Chick Could Have Been Fed	No. of Times Fed	Percentage
Dec. 23 to Dec. 27		7	4	57
Dec. 28 to Jan. 1	31 Dec., New moon	26	21	81
Jan. 2 to Jan. 6		35	30	86
Jan. 7 to Jan. 11		35	27	77
Jan. 12 to Jan. 16	13 Jan., Full moon	35	34	97
Jan. 17 to Jan. 21		36	32	89
Jan. 22 to Jan. 26		40	28	70
Jan. 27 to Jan. 30*	28 Jan., New moon	32	26	73
1941-42				
Jan. 22 to Jan. 26	17 Jan., New moon	8	7	87.5
Jan. 27 to Jan. 30		50	38	76
Jan. 31 to Feb. 4	1 Feb., Full moon	52	46	88.5
Feb. 5 to Feb. 9		83	61	73.5
Feb. 10 to Feb. 14		114	91	79.8
Feb. 15 to Feb. 19	16 Feb., New moon	50	38	76
Feb. 20 to Feb. 24		23	18	78.3

*Last day chicks weighed.

From the preceding table it would appear that generally speaking breeding adults return to feed their chicks irrespective of the state of the moon. In fact, during the interval containing the full moon, in each season, a higher percentage of chicks was fed than on darker nights. With the Storm Petrels during this same period the position was reversed for in 1940-41 only 23% were fed during January 12 and 16, and in 1941-42 73% from January 2 to 6, 66% from January 31 to February 4, and 55% from March 2 to 6. All these periods contained the full moon and the number of chicks fed was relatively low.

Of the two full moon intervals under consideration for Titi Wainuis the period from January 12 to 16, 1941, was easily the brightest, the interval in 1942 being quite cloudy with little direct moonlight. In spite of the light the first interval yielded the highest return of chicks fed, for out of a possible of 35 meals only one was missed, that one occurring on January 15. The meals ranged from 3 to 45½ grams but most of them were very moderate, 83% being under 20 grams.

On any ordinary dark night during the latter half of December, 1940, the Titi Wainuis were very numerous and their cries dominated the night noises till daylight. The same position applied both in 1938 and in 1941. By January 9, 1941, the moon was far enough advanced to show a bright light at 10.30 p.m. resulting in there being very few birds about. Five of the seven chicks under observation were not visited while one of the two fed received only a small meal, so that I began to form the impression that the parents stayed away. On the 10th all chicks were fed with large meals ranging from 14 to 32½ grams. Up till midnight it was fairly light but later it became overcast. On January 11 the moon was bright up to 2 a.m. before the clouds obscured it, and on this occasion three of the chicks were not fed. Then followed the 5-day full moon interval during which all chicks, except on one occasion, were fed.

On January 23, 1941, a dark night, only two of eight chicks being weighed were fed and these received 40 and 26 grams respectively. This night coupled with January 9 previously, a moonlight night, gives the lowest record that season for food transmitted in a single night. Hence there must be other factors apart from the moonlight that prevent feeding. On January 25, 1941, a heavy fog developed at 11 p.m. Three of the eight chicks were not fed while the others received 4, 5, 6, 8 and 30 grams respectively. Perhaps those parents which did not reach the island before 11 p.m. had to stay away, while the four light meals would seem to indicate that only one parent fed at those particular nests.

In 1941-42, 10 chicks were weighed during the period from January 26 to February 28, at which date the last had flown. Only twice were as many as three chicks left unfed, while on all the other nights the number not fed was less than three. It will be noted that the number of chicks fed during each 5-day interval was comparatively even.

To sum up, it would seem that feeding proceeds as usual during moonlight nights. As against this, Titi Wainuis are rarely seen and never heard on moonlight nights. It follows therefore from table XXII that feeding adults which arrive at the burrow without much preliminary circling and calling, are unnoticed. I firmly believe, too, supported by the witnessing of the arrival of breeding birds that this is the usual procedure of this type of bird irrespective of the condition of the night. Seemingly, they have an important mission in life and no time for other activities. Similar behaviour is exhibited by breeding Royal Albatrosses, which, when the owners of a nest, neither circle unnecessarily nor dally prior to landing.

Unemployed Birds.

During January, 1941, I noticed fewer Titi Wainuis in the air at night, and this diminution in numbers was especially marked after the moon early in the month. The same condition prevailed in January, 1942, when on the 16th of the month I observed that the numbers of this species had suddenly decreased. Full moon occurred on January 3. The procedure seems to be that after the moon early in January or perhaps late December, the island is inhabited largely only by birds feeding chicks, or, in other words, most of the unemployed birds have left the island for that year.

As already mentioned, when I reached the island in all three years, 1938, 1940 and 1941, just before Christmas, Titi Wainuis were very plentiful. So persistent and raucous was the calling from numerous throats that complete sleep was, for some nights, impossible. As January advanced these calls slowly diminished in intensity. I am of the opinion that these noisy chatterings came not from the breeding birds, which, I believe, after some brief hovering, landed, entered their burrows and relieved their mates, but from the throats of the unemployed population. It would appear then that the large numbers of Titi Wainuis circling and calling out on ordinary dark nights are unemployed birds still on the breeding grounds. If this surmise is correct the proportion of unemployed to breeding birds must be high.

During the early part of my visit from about December 20 to early January, Titi Wainuis were present in the burrows in the day time either in pairs or singly. At night a considerable amount of excavating and entering of occupied and unoccupied burrows took place, scant courtesy in this connection being shown at times to the rights of the smaller petrels. I have several records where Storm Petrels lost either their eggs or their chicks because of these vagabond Titi Wainuis. Between December 29, 1941 and January 25, 1942, I have recorded eight cases. On five occasions the egg had been scraped out, and on two occasions a young chick was ejected. One of these was dead, the other I removed and placed under a foster parent which had that night lost its egg because of a Titi Wainui. In the eighth case a chick, 32 days old was ejected and although I did not find it again I scarcely think it could have perished.

Moreover, of the 33 Storm Petrel chicks under observation in 1940-41, no less than six burrows were usurped by Titi Wainuis. Four of these contained a breeding pair of Titi Wainuis while two others were occupied by unemployed birds.

Neither do the Kuakas *(Pelecanoides urinatrix)* escape interference from these Prions. I had occasion once to take a breeding Kuaka to the tent for measuring and on returning it to the burrow I found a Titi Wainui in the burrow with the Kuaka chick. So far, I have no evidence, however, of Titi Wainuis ousting Kuakas which are in occupation or of a chick being scraped out. Kuaka chicks, of course, are guarded all the time by their parents till they are about 12 days old.

Of 18 pairs of Kuakas marked in burrows in 1940-41, three pairs had their homes occupied by Titi Wainuis. Two other pairs occupied an old Kuaka nest where only one bird had been ringed, while two more pairs of Titi Wainuis were in holes previously used as subsidiary burrows by Kuakas. In yet another case, in 1941-42, a Titi Wainui was incubating an egg while embedded in the floor of the nest was an old Kuaka egg. Of course, it is not known for sure whether the original Kaukas had been ejected from their home. These activities have contributed to my impression that Titi Wainuis are increasing in numbers.

There was no evidence that Titi Wainuis had been ousted from their burrows by Pararas *(Pachyptila vittata).* Where the former nested in the Mutton-bird area, however, considerable ejection had occurred. In its turn the Titi Wainui has to give way to the Mutton-bird which scrapes out any species which happens to be in its path. In 1942-43, I found a Titi Wainui sitting on an egg in an old Mutton-bird burrow which was occupied by the latter species in the previous season. Incubation continued until the end of December when I found the egg, on the verge of hatching scraped out into the night—an unemployed Mutton-bird had decided to take up residence. This was by no means an uncommon occurrence in the western sedge area.

An interesting case of a pair of unemployed birds occurred at nest 47 in 1940-41. On December 24 a nest was found with a single bird which was ringed. For the next two days there was no bird but on the 27th an unringed bird was present, which I took the occasion to ring. No further sign appeared till the 31st when slight excavations indicated that at least one bird had been home at night. Across the entrance to the burrow I erected sticks but no further sign of occupation occurred that season. Now, in both 1941-42 and in 1942-43, these birds returned to this burrow and succeeded in rearing a chick. It has occurred to me that this species may indulge in a year's preliminary courtship prior to the laying of eggs as seems to be the behaviour with the Royal Albatross.

Weights and Measurements of the Growing Chick.

In Table XXIII below are given the 9 a.m. and 9 p.m. weights of 17 chicks during part of their life in the burrow. The weights of seven chicks up to 28 days of age were taken in 1940-41 and are given first, followed by those for other chicks taken in 1941-42 from 29 days old till they flew.

In working out the data for the table all the weights concerned were put down in columns, one for each day. The columns were then divided into class intervals of four days, each column being then added up and averaged. These four averages were then averaged giving the average for each four day interval. In this way any tendency for extreme low or high individual weights was smoothed out. Each class interval therefore represents an average of many cases as indicated in columns 2 and 4. The last two intervals involve only a very few cases because some of the chicks had departed.

It will be noticed that between the two sections of the table there is a big difference in weight. This is due to the fact that in 1940-41 two of the chicks being weighed, though healthy, were much lighter than average chicks. Even so there is a general increase in weight up to the 41–44 day interval after which there is rapid decline, for some of the chicks begin to fly in the next interval while the bulk go between the 49–52 day period. The quantity of food given on the average per meal after the 41–44 day interval is distinctly less.

When the weights of 62 chicks (table XVI) were put down and averaged for their last eight days ashore there was shown to be a steady fall in weight. Table XVII indicates that nearly 70% of the chicks leave weighing between 105 and 124.9 grams. To sum up, it would appear that the chicks retain a comparatively heavy weight to within about four days of departing when many of them drop considerably during a short fast period of varying length, even up to six days in extreme cases. As against this 15.6% of the chicks were fed on the night before they left.

TABLE XXIII.

9 a.m. and 9 p.m. Weights of 7 Chicks to 28 Days of Age and then 10 Chicks Till They Flew, Grouped into Class Intervals of 4 Days.

Class Interval in Days 1940–41	No. of wts.	a.m. wts. gms.	No. of wts.	p.m. wts. gms.	Difference between even. and morn. wts.
1– 4	17	21.76	19	20.86	.9
5– 8	28	34.2	28	29.8	4.4
9–12	28	52.44	28	44.48	7.96
13–16	28	65.13	28	55.26	9.87
17–20	28	78.86	28	70.61	8.25
21–24	28	96.79	28	88.08	8.71
25–28	28	104.35	28	97.64	6.71
1941–42					
29–32	26	156.43	31	144.3	12.13
33–36	36	157.93	38	149.34	8.59
37–40	40	168.2	40	155.25	12.97
41–44	40	166.72	40	154.52	12.2
45–48	37	147.6	37	138.98	8.62
49–52	17	127.02	17	121.56	5.46
53–56	3	124.66	3	118.66	6.0

Some of the weights and increases in weights of the 10 chicks which were weighed in 1941-42 from 28 days of age are interesting. Four of them passed the 200-gram mark. One did so on one occasion only, two did it three times and one exceeded this weight four times. Chick 3R was 225 grams at 9 a.m. when 39 days old and left the island eight days later weighing 131 grams at 9 p.m. (see Graph). Actually chick 5 was the lightest, reaching a peak weight of only 148 grams at 9 a.m. when 34 days old; its final weight was 98 grams when 49 days old. This was the only one of the ten chicks to fly under 100 grams, the range being from 131 to 98.

The graph gives a good idea of the growth curve of a chick and also clearly shows the peaks and hollows caused by the irregular amount of food received, and by the weights when no feeding occurred. The 9 a.m. and 9 p.m. weights of three typical chicks are recorded. Those for chick 22 are complete up to the 39th day and indicate a greater number of nightly fasts than usual. The graph for chick 7R overlaps that for chick 22 and is inserted to indicate what happens during the final stages. This chick stayed ashore much longer than the average and did not attain a very heavy weight. Chick 3R was one of several, which besides being heavier in its earlier stages, reached a very heavy weight not long

before departure. In the two last chicks the method of attaining flying weight and the extent of the "starvation period" are clearly shown.

In the table below is given a summary of the weekly average measurements and weights of 10 Titi Wainui chicks from the day of hatching to their final days ashore in 1941-42.

TABLE XXIV.

Average Weekly Measurements and Weights of 10 Titi Wainui Chicks.

Feature	1st day	8th	15th	22nd	29th	36th	43rd	50th
Bill	12.33	14.33	15.96	17.92	19.65	20.94	21.62	21.77
Width	6.94	7.67	8.46	9.46	9.58	10.06	10.35	10.5
Depth					6.97	7.37	7.5	7.62
Wing	16.66	19.67	27.5	54.16	102	130.1	157.2	174.5
Tail			1.125	10	25.5	47.3	69.8	84.6
Toe and claw	16.08	19.04	24.79	30.21	35.85	38.33	38.77	38.77
Claw	3.29	3.88	4.29	5	5.72	6.3	6.45	6.45
Weight at 9 p.m. (gms.)	20.08*	38.1	66.83	88.86	129	148.5	151	118.2

* The 9 p.m. weights are influenced by meals during the day in some cases.

In order to find out if the bill of the fully fledged chick is smaller than that of the adult I measured the length, width and depth of 100 chicks and compared them with a 100 parents, 50 of each sex. The results are shown statistically in table XXV below. Before allowing that a difference between means is significant I have followed the ruling that it must be at least four times the value of the probable error of the difference. Applying this rule, the difference in depth is not significant, in length it is significant but not to any great extent, especially when the range is considered. In width, however, the difference is greater and is also apparent in the range. Even so these slight differences are not noticeable to the eye as is the case with adult and fledgling Storm Petrels. Certainly the difference is not as great as has been supposed and in considering this statement the weekly growth records given in table XXIV should be consulted.

Falla has shown (1940, pp. 219-220) that the width of the bill in fledgling Prions shrinks considerably after it has been dried, thereby explaining the small bill widths of some of the published measurements.

TABLE XXV.

A Comparison of the Bill Measurements of 100 Fully-fledged Chicks with 100 Parents, 50 of each Sex, all Taken on Whero in 1941-42.

Type of Bird	Bill	Mean mm.	σ mm.	PE_m	Range mm.
Adult	Length	22.11	.79	.05	20 to 24
	Width	10.88	.4	.025	10 to 12
	Depth	7.23	.28	.02	6 to 8½
Chick	Length	21.66	.8	.05	20 to 24¼
	Width	10.33	.41	.03	9¼ to 11
	Depth	7.34	.39	.026	6 to 8
Difference	Length	.45		±.07	
	Width	.55		±.04	
	Depth	.11		±.03	

THE ADULTS.

Already the reader will have gleaned a certain amount of information concerning the behaviour of the adults. Far greater irregularity in its habits distinguishes its behaviour from that of the Kuakas while compared with the Storm Petrel it is not quite so irregular. Rarely is the egg left cold as is the case with the Storm Petrel. The periodic span of incubation by each parent Titi Wainui is often longer than in the Storm Petrel while in the Kuaka the change of guard occurs daily. Though the chick is left alone very soon after it is hatched it does not experience the long fast periods endured by some of the Storm Petrel chicks. Moonlight nights do not influence the homecoming of the Titi Wainui parents to the same extent as the Storm Petrel parents, while the Kuakas are not affected at all. Unlike the Storm Petrels both the Titi Wainuis and the Kuakas are seen off-shore in the daytime during rough weather.

When handled, the adults are usually very noisy, uttering harsh cries and then often subsiding to canary-like calls. Possessing the power of biting quite ferociously they can inflict considerable pain when the point of the bill is inserted repeatedly in the same spot. Many of them when caught, and even when pulled out of the burrows in the daytime if they are attending chicks, cough up a quantity of food. When the hand is inserted into the burrow it is usually severely bitten by most birds.

The call of the Kuaka is a distinctive one, easily recognised, but with the Titi Wainui the calls are so many and diverse that I have not yet defined them all. Moreover, the presence of hundreds of Storm Petrels adds to the confusion and I am convinced that some of the calls of each species are very similar. The loud "Poor popper" and "Popper, popper, pop", as described in my Whero paper (1942, p. 93) are easily distinguished. Then there is the beautiful canary-like call uttered by both chicks and adults; the chicks as they get older will emit the "Poor popper" cry. The oldest in 1940–41 when playing with me would bite my hand, at the same time creating a comical situation with the incessant "Poor popper" cry. Some harsh cries, too, were uttered by the adults but I have not yet been able to enumerate them.

TABLE XXVI.
Population Statistics of Titi Wainuis on Whero, 1940-41 to 1941-42.

Description of Birds.	1940-41	1941-42
Breeding birds ringed	63	94
Breeding Birds not ringed	25	46
Other birds ringed	19	8
Birds which deserted eggs	24	22
Parents of unrecorded chicks	14	10
Unringed parents of chicks found on surface		84
	145	264
Chicks marked in burrow	29	73
Chicks marked on surface		42
	29	115

In the above table "breeding birds ringed" means those parents actually found in charge of a burrow on any part of the island. Some of the parents were not caught while in other cases the egg was deserted or some mishap overtook the chick before the adult could be ringed; this class is therefore called "breeding birds not ringed." Stray birds picked up on the surface and whose breeding status was unknown are classified as "other birds ringed." Wherever deserted eggs were found it was assumed that two birds were concerned and these are described as "birds with deserted eggs." "Parents of unrecorded chicks" belong to those chicks in burrows which for some reason were not recorded. In 1941–42, 42 chicks were picked up on the surface at night after they had left the burrow, and hence the class of parent "unringed parents found on surface."

It is interesting to review the Titi Wainui population of 400 as stated in my Whero paper (1942, p. 91). This is obviously far too small a number. Burrows are numerous in the western sedge area, more particularly in the northern end. In the sedge on top of the island and round the cliff edges they are also just as plentiful. Most of the chicks caught on the surface were taken in the *Muehlenbeckia*, and this fact coupled with the deafening noise that proceeds from the area early in the season produces sufficient evidence that the *Muehlenbeckia* is the dwelling place of many birds which were not found. Searching in the areas mentioned above did not yield success as the burrows in the sedge fell in easily and those in the *Muehlenbeckia* were inaccessible.

Taking into consideration all the factors concerned I should say that the Titi Wainui population of Whero is at least 800 birds. Arriving on the island, as I did, rather late in the Titi Wainui season I probably have not a thorough conception of the unemployed population which may be numerically greater. If so, the figure given above will be far too low.

As already indicated, the Skua *(Catharacta skua lonnbergi)* attacks and devours the Titi Wainui, but during my several sojourns, very seldom, to my knowledge, has a bird been captured on the island. I have records of two small chicks in 1940-41 and one in 1938–9 being taken. Of course, the remains of this species are plentiful in the middens but most of these must represent victims caught at sea. Already, I have discovered in these middens four sets of remains of two different species of petrels, which are not found on Whero.

The intriguing question of the domestic arrangements of individual birds and pairs from season to season will be reserved for a supplementary paper, by which time a considerable amount of data will be available. For the present it will be sufficient to say that from the experience of three consecutive seasons there is a tendency for the birds to pair up in the same burrow. There are, however, some pairs which have shifted to a neighbouring burrow, and also single birds which have been found in the same burrow with an unmarked and presumably a new mate. Some of these

single birds have been discovered in another burrow with a new mate, while the old burrow has been occupied by other birds. Above all, there is one case, and this is the first I have proved in the petrel world, of a "divorce." By that, I mean, I have located a bird with a new mate in possession of an egg, and only a few feet away is its previous season's mate, also with a fresh partner and incubating.

There is every evidence to support the fact, too, as in the case of the Mutton-bird, Storm Petrel and Kuaka, that the Titi Wainui returns to the same part of the island when on land.

A unique event occurred on December 31, 1940, when I found two birds in a burrow with an egg. The one incubating coughed up food and weighed 143 grams so it had evidently changed guard the night before; the second bird weighed 109 grams, but did not cough food. This marks the only occasion I have found two birds with an egg in the daytime.

Generally speaking, in the daytime, adult birds are not to be seen near the island, though on odd days, especially after rough weather, it is possible that they may be observed with the naked eye flying over the waves. On January 30, 1941, however, the appointed day for my departure from the island, the worst storm I experienced arose. Being storm-bound, I took the opportunity to watch the birds off-shore, and I noticed that all day Mutton-birds, Kuakas and Titi Wainuis were very numerous round the island; Kuakas and Mutton-birds had frequently been seen before. The Titi Wainuis were very close in and the Skuas, though sitting on the rocks watching them, made no attempt to attack. Evidently, the gale was a sufficient deterrent. The Titi Wainuis fed by submerging altogether or by "standing" on the water and ducking the head in, while sometimes they rested on the water and submerged the head. This habit of "standing" on the water seems to explain the presence of a ring of seaweed round the legs of the birds when they are handled on shore. Very little hydroplaning with wings out was noted, though sometimes one bird would proceed in this fashion for about a foot.

TABLE XXVII.

Measurements and Weights of 100 Breeding Titi Wainuis, 50 of Each Sex, Taken on Whero in 1941-42.

Feature	Mean mm.	σ mm.	PE_m	Range mm.
Bill				
Length	22.11	.79	.05	20 to 24
Width	10.88	.4	.025	10 to 12
Depth	7.23	.28	.02	6 to 8.5
Wing	182.5	3.43	.22	175 to 191
Tail	91.69	2.93	.19	86 to 98
Toe and claw	40.4	1.6	.1	35 to 45
Claw	7.23	.64	.04	5¾ to 9
	gms.	gms.		gms.
Weight	131.8	13.75	.92	100 to 162

TABLE XXVIII.

Measurements of 14 Birds Taken on the Poor Knights, November, 1940.

Feature	Mean mm.	σ mm.	PE_m	Range mm.
Bill				
Length	23.36	.76	.14	22½ to 25½
Width	11.75	.46	.08	11 to 12½
Wing	183.86	4.86	.9	171 to 190
Tail	89.57	3.06	.57	82 to 94
Toe	40	1.22	.23	38½ to 42

TABLE XXIX.

The Difference Statistically Between Whero and Poor Knights Birds.

	Bill Length	Bill Width	Wing	Tail	Toe
Difference in mm.	1.25	.87	1.43	2.12	.4
PE_d	.15	.08	.93	.6	.39

From data given in the three above tables it is possible to compare the Whero birds with 14 of those measured on the Poor Knights off the east coast of North Auckland. The measurements are given by Buddle (1941, p. 60). The difference in the two sets in wing, tail and toe is not significant. In the length and width of the bill, however, the Poor Knights birds are significantly larger than those from Whero.

Falla (1940, pp. 229-231) believes that the *turtur* assemblage may be divisible into two groups, a small-billed type from Stewart Island, from a point west of Australia, and still present in the Chatham Islands population, and a robust-billed type north of these areas including Bass Strait.

The figures from the Poor Knights would seem to support these contentions. Those given in table XXX even though some of the averages are greater than those in table XXVII, indicate that the range in all cases falls within the range of birds handled on Whero. It would be interesting to have a large series of measurements from birds of the more northerly breeding areas. It should be recalled as stated further back that *turtur* on the Poor Knights breeds much earlier than the type on Whero.

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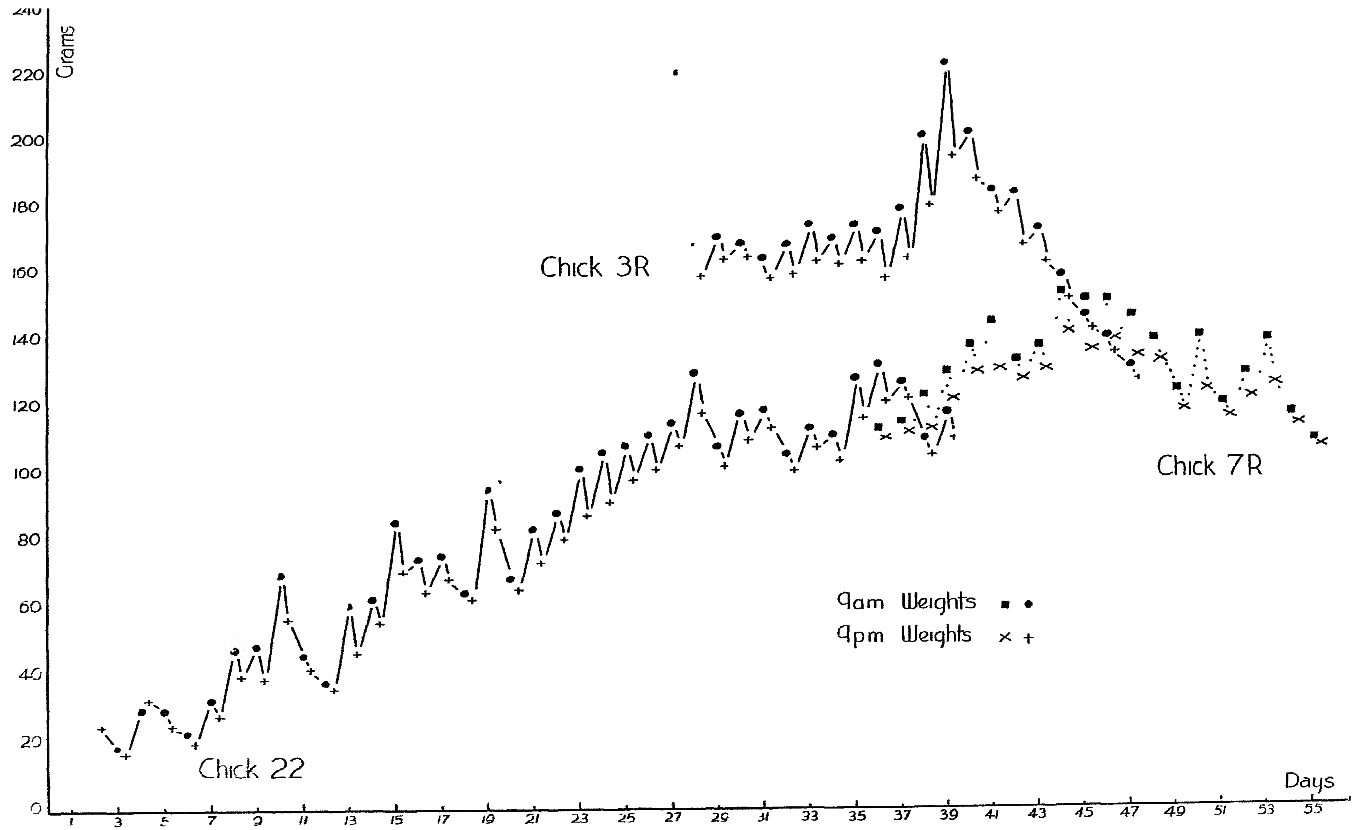

The graph for Chick 22 ends on the 39th day; that for Chick 7R begins on the 36th day.
9 a.m. and 9 p.m. weights of three Titi Wainui chicks during a portion of their life in the burrow.

Facing page 180.

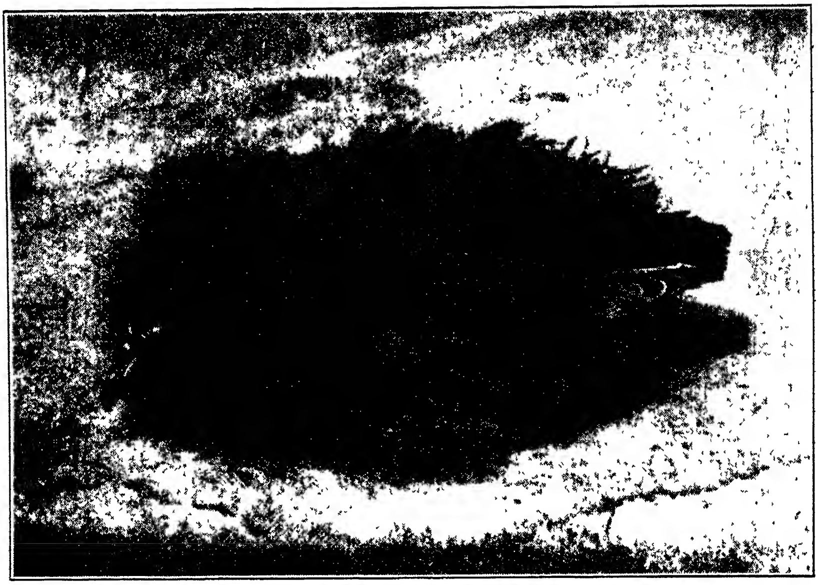

FIG. 1.
Titi Wainui Chick 40 Days Old 29/1/41.

FIG 2.
Another Chick 46 Days Old 12/2/42. Note rapid disappearance of down at this stage.

TABLE XXX.

Measurements of *Pachyptila turtur* given by Other Observers.

Authority	Locality	No. of Cases	Bill	Width	Depth	Wing	Tail	Tarsus	Toe
Murphy (1936, p. 631)	At sea off N. end of N.Z.	10	21.8–24.2 (23.3)	10 –11.8 (10.9)		174–187 (180.3)	81.5–93.4 (85.7)	29.4–31.9 (30.7)	35–39.3 (36.7)
Falla (1940, p. 230)	Chatham Island	4	21 –23 (22)	10 –11.2 (10.8)		169–178 (173.8)	85 –92 (90)	29 –30 (29.8)	36–39 (37)
	Motunau Island	3	21 –23 (22.3)	10.7 –11 (10.9)		182–185 (183.3)	90 –94 (92)	31 –32 (31.3)	38–42 (40.7)
	Jacques Lees	4	21 –23 (21.8)	9.8 –10 (10)		175–178 (176.3)	85 –90 (87)	30 –31 (30.3)	36–39 (37.3)
	Bench Island	9	20 –22.5 (21.8)	10.75–12 (11.3)		174–185 (179.3)			
Fleming (1939, p. 400)	Chatham Island	5	23	10 –11 (10.8)	6.5–7 (6.9)	172–182 (177)	80 –88 (85)	28 –30 (28.7)	35–38 (37)
Wood Jones (1937, pp. 187–8)	Lady Julia Percy Island	8	23 –24 (23.1)	10.5 –11 (10.8)		165–174 (170.3)		30 –32 (31.5)	
	Lawrence Rocks	2	22 –23	10 –10.5		169–171		31 –32	

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Chronic Osteomyelitis Occurring in *Emeus crassus*

C. C. ANDERSON and J. H. SORENSEN.

[*Read before the Southland Branch, April 30, 1942; received by the Editor, March 29, 1944; issued separately, September, 1944.*]

AMONG moa remains recovered at Back Beach, Riverton, in 1939 by Mr. John Thomson, jun., and presented by him to the Southland Museum, was a partial skeleton of an immature *Emeus crassus* (Owen), the right tarso-metatarsus of which showed a decided pathological lesion.

Diseased conditions among moa bones have been noted on previous occasions, Booth (1874, p. 124) for instance, stating: " A disease of the foot appeared to have been very prevalent amongst them, as a great number of the joints presented unmistakeable indications of rot, so much so that some of the toe-joints had even grown together." More recently, in a letter to one of the authors, Dr. Gilbert Archey, Director of the Auckland Institute and Museum, states that some of the moa bones in his institution show pathological conditions. He states that the type of *Pachyornis mappini* (Archey) has the claw joint of the outer toe fused to the fourth, whilst an example of *Euryapteryx exilis* (Hutton) from Doubtless Bay has the basal joint of the hind toe fused to the back of the metatarsus. Dr. Archey also states that inter-muscular or interligamentary bone growth and penetration is common in leg-bones and vertebrae which thereby become very jagged in presumably older specimens.

Dr. R. A. Falla, Director of the Canterbury Museum, has stated that several examples of a diseased state in moa bones occur in the collections under his charge, but the authors have no particulars of the actual condition.

It appears that most, if not all, diseased conditions occurring in moa bones, and previously reported, are degrees of bone fusion and associated with advancing age. The condition to be described by the authors is not one of these and occurs in a juvenile bird.

In order to find out if a similar condition had been noted in other members of the Ratite group, various institutions, both at Home and abroad, were written to, requesting information. Almost all replies were negative ones with the exception of one from the American Museum of Natural History in New York, and one from the New York Zoological Society. John T. Zimmer, Executive Curator of the former institution, stated that, after going over their collections of ostriches and their allies, he found one specimen of a male cassowary of undetermined species which showed decided pathological lesions at the upper ends of both tarsi and extending well down in front. In the rest of the material housed at the institution he was unable to detect any similar condition.

Lee S. Crandall, Curator of Birds, New York Zoological Society, stated that Dr. L. J. Goss, veterinarian at the institution, had been carefully through the records of his department, but could find nothing describing a pathological condition and could recall nothing of the sort from his own experience. Mr. Crandall stated that he had certainly seen birds of the group with bone enlargements suggestive of healed lesions, but could not recall a complete history of such a case.

The remains to which the diseased tarso-metatarsus belong have been identified as *Emeus crassus* (Owen). They include a damaged pelvis, some vertebrae, part of the lower mandible, a broken sternum, some ribs, toes and sundry small bones, both femora, both tibio-tarsi and the diseased tarsometatarsus. Immaturity is shown by the lack of fusion of epiphyses at the knee and by the roughening of the ends of the long bones beneath their articular cartilaginous coverings. Of those bones which have been preserved no other shows any macroscopic evidence of disease.

MACROSOCOPIC APPEARANCE.

The affected bone presents marked expansion of the shaft with a large central cavity and large anterior and posterior openings in the bone. (Figs. 1 and 2.)

On the anterior surface (Fig. 1) the epiphyseal line is still visible at the proximal end of the bone. The expansion of the bone commences immediately beyond this on the lateral aspect and extends almost to the base of the metatarsal element. The involucrum, or subperiosteal new bone, is very dense throughout this area. This new bone extends across the front of the specimen immediately distal to the large anterior fossa and continues down its medial aspect to the base of the internal metatarsal element. There is a large anterior opening in the bone 4·2 cm. long by 3·5 cm. wide. The neck of the internal metatarsal element shows a patch of subperiosteal roughening on its anterior and medial aspects.

On the posterior surface (Fig. 2), the subperiosteal roughening commences just distal to the twin foramina and extends laterally and medially to the expanded regions of the shaft. The involucrum is particularly thick and spongy on the medial aspect of the large central opening, which is 5 cm. long by 4 cm. wide; its distal limits correspond with those on the anterior aspect of the bone. Distally at the neck of the internal metatarsal element there is a small sinus leading down into the depth of the bone. It is situated at the centre of a small raised roughened area of bone 15 mm. across.

The medial surface of the specimen (Fig. 3) is of particular interest, in that it shows two enormous bosses of involucrum occurring in front of and behind a narrow strip of bone which appears to have been the original medial border. There is a small cloaca at the distal aspect of this furrow and several more in the anterior mass of involucrum. Additional interest is aroused by the fact that a similar narrow groove is present in the same region on a healthy bone, so that one is inclined to presume that this is

caused by the presence of a tendon or similar structure. In contradistinction to the marked thickening and density of the lateral border, the involucrum medially is both thin and spongy, hence the numerous cloacae. Distally, the band of roughening can be seen to extend right across the neck of the internal metatarsal element from front to back.

Radiographic Appearance.

Comparative antero-posterior radiographs of the specimen (Fig. 4) and of a similar bone from the healthy bird (Fig. 5) show the great changes produced by infection. A large cavity occupies the central portion of the expanded shaft and from here the disease extends both proximally and distally.

Proximally, on the medial aspect of the specimen, the lesion, as shown by the increased density of the bone (osteitic reaction) has extended right to the articular surface, while the intervening bone shows irregularly mingled areas of rarefaction and increased density.

Distally, the infective process appears to have involved the medial aspect of the metatarsal elements rather than the external one, though this same irregular alternation of increased density and rarefaction extends down to the necks of the middle and internal metatarsal elements. There are three or four small areas of necrosis in this region of the middle metatarsal and one large one, approximately 15 mm. in diameter, in the internal element.

The radiograph of the healthy bone shows the bony trabeculae and how the lines of force are distributed normally.

The lateral radiograph (Fig. 6) discloses the density of the bone above and below the lesion and the spongy nature of the involucrum which formed posteriorly; it also gives a very fair idea of the ramifications of the large central cavity. In this film the cavity previously noted in the internal metatarsal is seen to affect mainly the posterior part of the bone.

Summary.

The macroscopic and radiological appearances are those of a chronic long-standing osteomyelitis of the right tarsometatarsal bone with a small metastatic abscess in the neck of the internal metatarsal element, and with commencing necrosis in the neck of the middle metatarsal. The three features of main interest in the actual specimen itself are (1) the large irregular cavity, (2) the great expansion of the bone and (3) the great density of the lateral aspect of the bone.

No other lesion was discovered in any of the remaining bones recovered.

Acknowledgments.

The authors wish to acknowledge their indebtedness to the Southland Museum for permission to describe the diseased bone and to all those who supplied information upon request.

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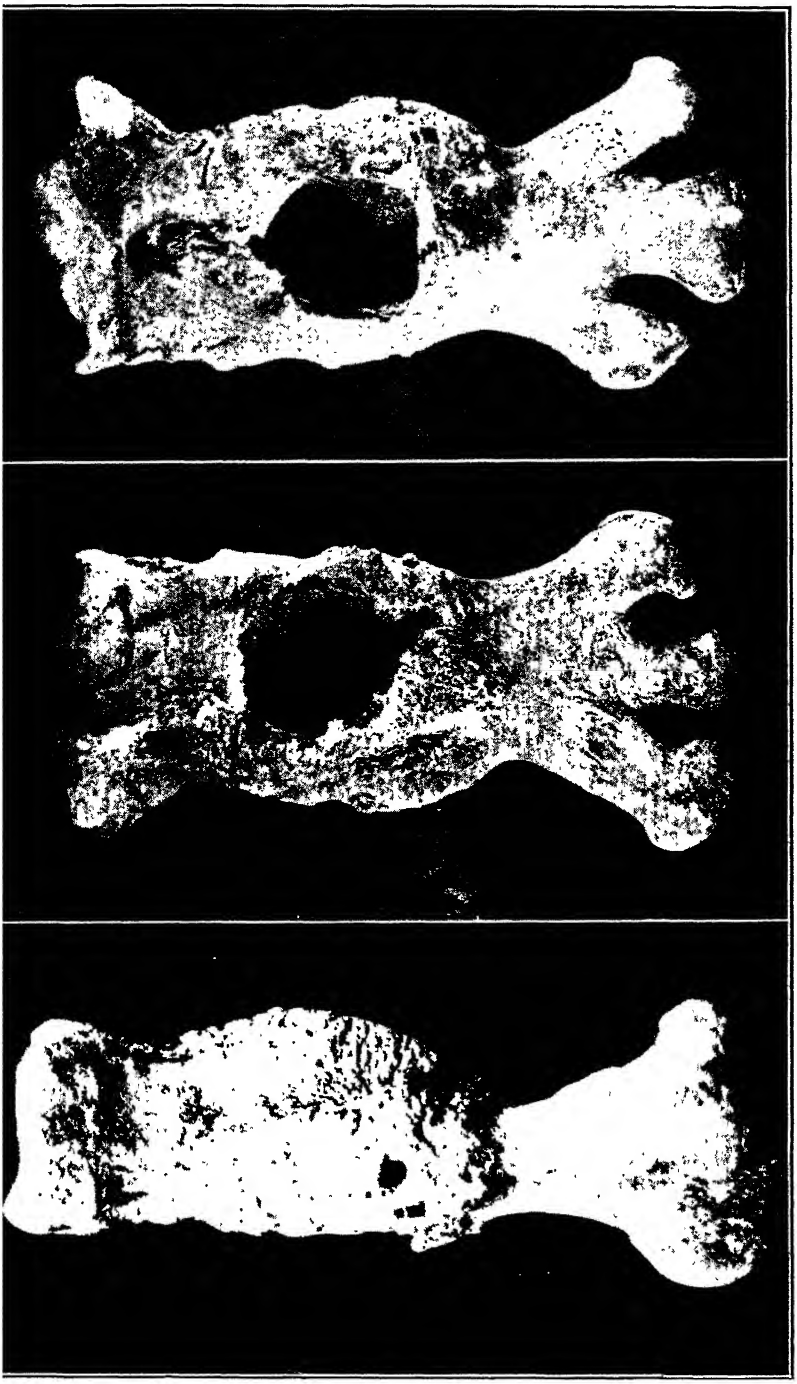

Right Tarso-metatarsus of *Emeus crassus* (Owen).

Fig. 1. Anterior Surface.

Fig. 2. Posterior Surface.

Fig. 3. Medial Aspect.

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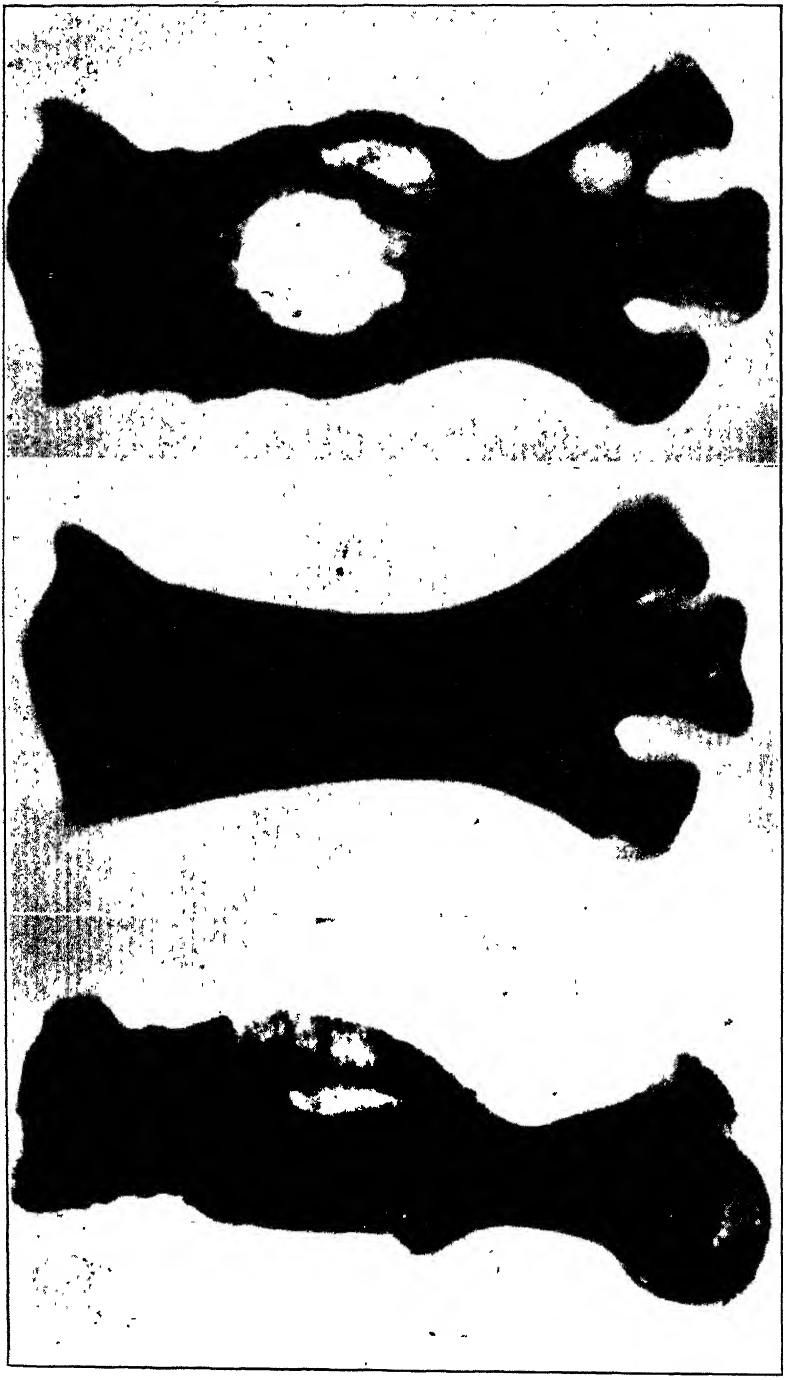

Right Tarso-metatarsus of *Emeus crassus* (Owen).

Fig. 6. Lateral Radiograph of Specimen.

Fig. 5. Antero-posterior Radiograph of a Normal Bone.

Fig. 4. Antero-posterior Radiograph of Specimen.

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Vol. 74, Part 2, pp. 185–195, Plates 24–25.

The Survey and Classification of Land in New Zealand: A Basis for Planning.

By Kenneth B. Cumberland.

[*Read before Canterbury Branch, March 1, 1944; received by the Editor, April 24, 1944; issued separately September, 1944.*]

Introduction.

To satisfy the simple needs of all the world's 2,000,000,000 people is to go a long way to building peace on a solid foundation. The world of 1938 was a hungry world. War has but aggravated a condition which, although little publicised and less appreciated, was already present. If the architects of the new world-order find it possible to provide humanity as a whole with an ample and nutritive diet, they will banish a most potent primary cause of international strife and misunderstanding. To do this is a gigantic task, but one which is not beyond the limits of possibility. At bottom, it requires a wide and popular revaluation of the inherent importance of the land. In practice, it necessitates what amounts to an almost world-wide agricultural revolution. It demands a better use of soil in most parts of the world and—paradoxically enough—it requires higher use of land also in those parts of the world where agriculture has, until very recently, been considered most "efficient."

Another very disturbing fact characterised (especially) the inter-war years. It has been made abundantly apparent (first in the United States and later in practically all other parts of the world occupied sparsely during the past three centuries by an immigrant, European culture) that not only is the fertility of soil being rapidly depleted, but also that the soil itself is fast disappearing. Yet soil must long, if not permanently, remain the basis of expanded food production and of increasing numbers of industrial raw materials.

New Zealand is concerned with both these problems. Soil exhaustion occurs in New Zealand whenever and wherever land is given inadequate care: such was the case on the bonanza grain farms of Canterbury during the 1870's and 1880's: such is also the case to-day in the Waikato, for example, where production is in decline. New Zealand's soil erosion problem is a formidable one. Its extent and nature have already been discussed (Taylor, 1938, D.S.I.R. Bulletin No. 77, 1939 and Cumberland, 1943). New Zealand is also—if less directly—concerned with the raising of world dietary standards. The Dominion can set the nations an emulative example of comfort, health and diet; and it can do much to serve that portion of humanity which is much less favoured, by increasing New Zealand's output and export of highly nutritive and most urgently required foodstuffs.

Fortunately, the conservation of soil, the restoration and increase of fertility and the expansion of productivity are intimately related. Where soil conservation is an established feature of national policy, it has been shown that the stabilisation of soil by erosion-resistant practices results in higher per-acre yields and is an important factor in helping to meet war-heightened demands (Bennett, 1943 and others). Soil conservation and maximum food production, alike, demand an understanding of the needs of the land, an appreciation of its capabilities and the most intelligent possible use of such land in accordance with its requirements. Proper use of land is governed by certain phsyical factors. Its capabilities, however, are affected by cultural factors—technological, economic and social. If a nation is to increase its primary production to the greatest possible extent, it must know its resources, both physical and cultural. A nation-wide stocktaking of New Zealand's resources is imperative if the Dominion is to play its proper part in, and make its maximum contribution to, the post-war world.

THE PROBLEM.

Had the war not intervened, New Zealand would have celebrated its centenary in 1940 with the preparation and publication of a modern "New Zealand Domesday Book." The value of the Centennial Atlas if, and when, completed will be inestimable. But the atlas is intended to map the resources and productivity of the Dominion only on a small scale. More detailed information is necessary in order to have an adequate factual base on which to found plans for the future use of New Zealand's land and soil. Ideally, detailed methods of field analysis*, applied from end to end of the Dominion, would be most desirable. Such methods have already been employed in the restricted area of the Heretaunga Plains (Connell, Kidson, *et. al,* 1939), and are being used to survey one important highly specialised aspect of land by the Soil Survey Division of the Department of Scientific and Industrial Research. These methods supply detailed, accurate, quantitative data; but they fail when applied to large areas and to *all* the important aspects of land, because of the time and cost involved. Time will be an important consideration in New Zealand if the Dominion is to be in a position to design an enlarged wartime or immediately post-war output of foodstuffs. The demand for factual information is likely to be early, urgent and insistent. On the other hand, traverse and generalised reconnaissance methods have been applied to certain limited aspects of land (Hilgendorf, 1935; Madden, 1940; Cumberland, 1941). For present purposes these are inadequate since, because of the methods employed, they are open to

* A good example of detailed field analysis is that employed by the United States Soil Conservation Service and described by E. A. Norton, Soil Conservation Survey Handbook, *U.S. Dept. of Agric. Misc. Publs. No. 352.* Such detailed methods might be employed in New Zealand once reconnaissance survey has demonstrated the extent and location of problem areas requiring such treatment.

inaccuracy and also because they are concerned, even in aggregate, with but few of the relevant data.

The crux of the technical problem lies in bridging the gap between methods of detailed field analysis and those of reconnaissance, and in collecting at one time a variety of data—physical and cultural—which alone, when synthesised, are sufficient to suggest the most efficient, permanent and productive use of land. To survey present use of land is not in itself adequate. Present use (in the "new lands," at least) is often inappropriate and inefficient, as the prevalence of deterioration, weeds and soil erosion in New Zealand, for example, clearly indicate. Contemporary use does not necessarily reflect the present capabilities or the ultimate potentialities of the land. Nor does a detailed soil survey provide a complete and satisfactory factual base in the absence of economic and social data. It appears necessary to the present task to consider the whole Dominion and to classify sufficiently small areas of land into broad categories adapted to different kinds and degrees of use; and this classification must be based on the investigation. the mapping, and the *integration of all relevant factors.* Such a classification would be immediately suitable as a basis for planning. Once international and national policies are announced, the most efficient use would then be known of the different categories of land in the light of such policy. (The Atlantic Charter already provides the framework for these policies; and, for New Zealand especially, the Hot Springs Conference has drawn the more essential features of the picture within that framework. Some of the many other advantages of this form of land classification are discussed below).

THE SUGGESTED SOLUTION: NOTATION, PROCEDURE AND EQUIPMENT.

It is fortunate that a technique for making such a survey has been worked out, adequately tested and its value demonstrated. The Land Classification (formerly Geography) Section of the Tennessee Valley Authority devised a "unit area method of land classification" and applied it to over 41,000 square miles of the Tennessee drainage basin. The unit area method is described by Hudson (1936). The principal contribution of the present paper is an adaptation of this method to suit New Zealand's 103,000 square miles and to fit the great variety of regional conditions found in the Dominion.

The original method proved to be a successful attempt to achieve the greatest possible accuracy and detail with field investigation within certain practical considerations of time and cost. Its unique qualities are: (1) the application of "fractional-code notations" (Jones and Finch, 1925) to land units of not less than 200 acres; (2) the use of aerial photographs as base maps, and (3) a consideration of all those items best calculated to serve land planning. The following adaptation is suitable for use with either aerial mosaics or the new One Inch Topographic Maps which by the end of 1943, were scheduled to cover 48,000 square miles—almost half the area of the Dominion. The adaptation has been tried out ten-

tatively near Christchurch (Plate 25). It will, of course, need some modification and considerable quantitive definition if, and when, it is applied to the constrasting variety of situations existing in New Zealand's relatively small area.

Tables I, II, III, IV, and V, the notes, and the appended complete fraction illustrate the field recording and notation of the unit area method of land survey and use classification.

TABLE I.—THE USE OF THE LAND.

On the basis of which homogeneous unit areas are defined (noted on photographs and/or maps by the digits in the *numerator* of the *long* fraction).

First Digit.	Second Digit.
Contemporary Land Use.	Farm and Station Crops, Stock and Economy.
1. Agricultural Land (ploughed in farm year of survey). 2. Pasture Land (in rotation where grass exceeds other crops in area). 3. Pasture Land (permanent and semi-permanent). 4. Native Grassland (mainly tussock) [4] depleted *(Raoulia).* (4) deteriorated. 5. Scrub, Fern and Exotic Weeds. 6. Forest Land (native *and* exotic). 7. Unused (and not covered by other classes yet suitable for some form of use—e.g., afforestation, recreation). 8. Unused (not suited to economic use of any kind). 9. Built-up Urban Area. 0. Land outside Urban Areas occupied by Manufacturing or Mining Enterprises.	A. Cereals. B. Root, Pulse and Green Fodder Crops (including main crop potatoes). C. Grass and Clover for Seed. D. Orcharding. E. Market Gardening and Nurseries. F. Other Intensive Crops (early potatoes, onions, tobacco, hops, etc.). G. Store Sheep. H. Sheep Breeding and Rearing. J. Fattening of Sheep and Lambs. K. Dairying. L. Station Cattle. M. Pigs and/or Poultry.

Third Digit.	Fourth Digit.
Amount of Idle Land.	Amount of Land rendered Unproductive by Weeds.
1. Little. 2. Limited. 3. Considerable. 4. Excessive.	1. Little. 2. Limited. 3. Considerable. 4. Excessive.

Fifth Digit.	Sixth Digit.	Seventh Digit.
Quality of Farmstead, Buildings, Plantations, Shelter, Equipment, Fences, etc.	Kind of Native and Exotic Weeds Present.	Size of Holdings.
1. Excellent. 2. Good. 3. Medium. 4. Poor. 5. Very Poor.	1. Fern. 2. Manuka. 3. Other Natives. 4. Gorse. 5. Broom. 6. Blackberry. 7. Wild Briar. 8. Ragwort. 9. Other Exotic	1. Very large [(1) excessive]. 2. Large [(2) excessive]. 3. Medium. 4. Small. 5. Very small. [(5) too small].

Near Winton (Southland).

$$\frac{2A\text{–}B\text{–}K\ 11253}{121122}\ \ \frac{2}{1} + \mathrm{III}$$

Inland Taranaki.

$$\frac{1}{2}$$

$$\frac{5H444\ \bar{4}\ 2}{524334}\quad \frac{5}{5}\quad 0$$

Bowenvale—McCormick's Bay, Christchurch.

2. 6 is not further characterised because forest types, timber values, etc., are adequately cared for by the State Forest Service.

3. The second digit may be expressed by joining several letters; though, to be included, each must have some considerable emphasis (see fraction example below).

4. Where several weeds are present in similar quantities, the sixth digit may be expressed thus:—

$$\frac{\frac{5}{6}}{8}$$

5. The third, fourth, fifth, and seventh digit descriptions require precise definition after the method has had a trial in different areas.

TABLE II.—LAND CLASSIFICATION.

On the Basis of the Quality of its Contemporary Use (noted on photographs and/or maps by the *numerator* of the *short* fraction).

Class.	Qualities.
1.	Unit areas characterised by the following features occurring individually or in combination: (i) Little (or no) idle land (ii) Little (or no) land rendered unproductive by weeds, (iii) Excellent buildings, equipment, etc., and (iv) any other evidence of a high standard of living.
2.	Unit areas characterised by the following features occurring individually or in combination: (i) Little idle land, (ii) Land largely free from weeds, (iii) Good buildings, etc., and (iv) Any other evidence of a comfortable standard of living.
3.	Unit areas characterised by the following features occurring individually or in combination: (i) Considerable idle land, (ii) A limited field coverage of weeds, (iii) Medium quality buildings, fences, etc., and (iv) Other evidence of an average standard of living.
4.	Unit areas characterised by the following features occurring individually or in combination: (i) Considerable idle or neglected land, (ii) A large amount of land occupied by weeds, (iii) Poor farmsteads and equipment, and (iv) Any other evidence of a moderate to low standard of living.
5.	Unit areas characterised by the following features, occurring individually or in combination:—(i) Excessive amounts of idle land, (ii) Large areas rendered unproductive by weeds or abandoned, (iii) Very poor or limited buildings and equipment, and (iv) Any other evidence of a low and unsatisfactory standard of living.

NOTES.

1. This classification on the basis of the (contemporary) agricultural use of land is judged principally on the long fraction numerator indices 3, 4, and 5, and any other observable indications of prosperity (or otherwise) and of fitting (or unsatisfactory) use whether recorded or not.

2. The five classes are noted by numerals from 1 to 5 in the numerator of the short fraction which appears as a suffix to the long fraction.

TABLE III.—THE PHYSICAL CONDITIONS OF THE LAND.

On the basis of which homogeneous unit areas are defined (noted on photographs and/or maps by the digits in the *denominator* of the *long* fraction).

First Digit.	Second Digit	Third Digit.
Slope.	Drainage.	Soil Erosion.
1. Relatively level. 2. Relatively level to undulating. 3. Undulating to moderately hilly. 4. Hilly. 5. Steep.	1. Thorough. 2. Adequate. 3. Poor. 4. Very poor. 5. Excessive.	1. Little or no accelerated erosion. 2. Soil erosion present—not serious. 3. Some obvious "slipping," sheet wash, rilling, gullying, or wind erosion. 4. Much "slipping," sheet wash, gullying, or wind erosion. 5. Excessive "slipping," gullying, sheet wash, or wind erosion.
Fourth Digit.	Fifth Digit.	Sixth Digit.
Rock Exposure.	Soil Fertility.	Soil Depth.
1. Little or none. 2. Limited. 3. Considerable. 4. Excessive 5. Barren.	1. Exceptionally fertile. 2. Fertile. 3. Moderately fertile. 4. Low in fertility. 5. Very low in fertility.	1. Deep (more than 6ft.). 2. Moderate (4ft.—6ft.). 3. Adequate (2ft.—4ft.). 4. Shallow (1ft.—2ft.). 5. Very shallow (less than 1ft.).

NOTES.

1. Other physical data are often necessary, most important amongst which are the climatic and meteorological. Sufficient information of this sort for almost any settled area is available in the Meteorological Office. Other data may be collected, but not necessarily recorded in the notation on field mosaics and map.

2. The descriptive terms suggested here practically all require precise quantitative or qualitative definition after trial.

TABLE IV.—LAND CLASSIFICATION.

On the Basis of the Quality of its Present Physical Conditions (noted on photographs and/or maps by the *denominator* of the *short* fraction).

Class	Quality.
1.	Unit areas characterised by the following features occurring individually or in combination:—(i) relatively level or moderately undulating surface, (ii) adequate or thorough drainage, (iii) little or no accelerated erosion, (iv) deep and fertile soil, and (v) little or no rock exposure.
2.	Unit areas characterised by the following features occurring individually or in combination:—(i) relatively level to undulating surface, (ii) adequate or thorough drainage, (iii) little soil erosion present, (iv) moderately deep and fertile soils, and (v) limited exposure of rock.
3.	Unit areas characterised by the following features occurring individually or in combination:—(i) undulating or moderately hilly surface, (ii) adequate or thorough drainage, (iii) soil erosion present or obvious (erosion control economically feasible), (iv) soils adequately deep and moderately fertile, and (v) limited rock exposures.

4.	Unit areas characterised by the following features occurring individually or in combination:—(i) hilly surface, (ii) poor or excessive drainage, (iii) much obvious and serious soil erosion (continuation of contemporary practice would render control and rehabilitation economically impracticable), (iv) shallow soil, low in fertility, and (v) considerable rock exposure.
5.	Unit areas characterised by the following features occurring individually or in combination:—(i) steep slopes, (ii) very poor or excessive drainage, (iii) much or excessive soil erosion (beyond the point where rehabilitation is feasible other than by profound changes of use—e.g. by afforestation or reforestation), (iv) shallow and stony soil of very low fertility and (v) excessive rock exposures.

NOTES.

1. The classes represent the judgment of the fieldman and are based on all observable physical factors whether recorded or not.
2. The five classes are noted by the numerals 1 to 5 in the dominator of the short (suffix) fraction.

TABLE V.—FINAL LAND CLASSIFICATION.

On the Basis of the Economic Status of its People, its Inherent Agricultural Qualities, and its Physical Conditions (noted on photographs and/or maps by Roman numerals after the fractions).

Class.	Qualities.
— I	*Unit areas which, in general, are unsuited to agricultural and pastoral use and occupance: of value only for forest use, for recreational, water conservation, and wild life reserves.* These units are characterised especially by the following indices occurring individually or in combination:—(i) evidences of low standards of living, (ii) large holdings, extensive practices, (iii) excessive amounts of idle land, (iv) excessive amounts of weed-invaded land, (v) poor homesteads, and equipment, and dilapidated fences, etc., (vi) much bare rock, (vii) steep slopes, (viii) poor or excessive drainage, (ix) thin, stony, and infertile soils, and (x) excessive amounts of accelerated erosion.
O	*Unit areas in which occupance is marginal and unstable and in which farm and station problems are critical. In the main these problems require marked readjustment and/or reorientation of economic activities and land use.* These units are characterised especially by the following indices occurring individually or in combination:—(i) evidences of unsatisfactory standards of living, (ii) large or too small holdings, (iii) much idle land, (iv) considerable areas of weed invasion, (v) poor homesteads, inadequate equipment, shelter, etc., (vi) considerable bare rock, (vii) hilly to steep surface, (viii) poor or excessive drainage, (ix) shallow soils of limited fertility and (x) much accelerated erosion.
+ I	*Unit areas in which farm and station problems are moderately critical and in which occupance may be stabilised (and sometimes increased) and standards improved by intensive programmes of assistance, education and demonstration.* These units are characterised especially by the following indices occurring individually or in combination:—(i) medium living standards, (ii) considerable idle land, (iii) limited to considerable areas of weed invasion, (iv) medium quality homesteads and equipment, (v) ill-designed farm layout and insufficient fencing, (vi) limited rock exposure, (vii) moderately hilly to hilly surface, (viii) adequate drainage, (ix) adequately deep soils of moderate fertiilty and (x) some obvious soil erosion amenable to control.

+ II *Unit areas in which farm and station problems are not critical, and in which a stabilised occupance might be increased and intensified. Problems can readily be solved by programmes of instruction and demonstration.*

These units are characterised especially by the following indices occurring individually or in combination:—(i) good standards of living, (ii) little idle land, (iii) largely free from weed invasion, (iv) good homesteads and equipment, (v) little or no rock exposure, (vi) relatively level to undulating or moderately hilly surface, (vii) adequate drainage, (viii) deep and moderately fertile to fertile soils and (ix) soil erosion sometimes present but never serious.

+ III *Unit areas in which no significant farm and station problems are apparent, and in which improved techniques and intensified use would most readily increase productivity and accommodate denser occupance patterns.*

These units are characterised especially by the following indices occurring individually or in combination:—(i) excellent living standards, (ii) little or no idle land, (iii) free from weeds, (iv) excellent farmsteads, fencing and facilities, (v) no rock exposure, (vi) relatively level to moderately undulating surface, (vii) adequate or thorough drainage, (viii) deep, fertile, or exceptionally fertile soils and (ix) little or no accelerated erosion.

NOTES.

1. This final classification will need constant modification in the light of trial, experience, and application. The present suggestion is tentative only.
2. In part the Roman numerals represent a summary of their accompanying long and short fractions, but the entire complex—physical and cultural—must be considered and appraised carefully in all pertinent, observable respects before final field judgment is made.

COMPLETE SPECIMEN NOTATION.

$$\frac{1\ \text{D–E}\ 1\ 1\ 2\ \overset{5}{\overline{6}}\ 5}{2\ 1\ 3\ 1\ 3\ 2} \qquad \frac{2}{3} \qquad \overline{\underline{\text{II}}}$$

Photographic mosaics might prove more serviceable than the topographic maps, and are essential, of course, for those areas not as yet covered by the new topographic sheets. They could be printed on a scale greater than that of the One-inch Topographic Map (i.e., greater than 1 : 63,360), and they provide a variety of information not shown on the maps. In addition to aerial mosaics and map sheets (properly indexed so that they can be filed and recorded), clinometers, soil augers and cars complete the field equipment.

Field procedure runs, in outline, as follows. Essentially homogeneous unit areas are recognised tentatively from the base data (on maps and photographs) or as a result of the investigator's prior acquaintance with the region. The boundaries of these tentative units are sketched on the mosaic and an experimental characterisation of the unit is made and recorded on the mosaic in the form of a long fraction. Outdoors, the boundaries are checked and corrected at every point to which access is possible, and the final, representative long fraction is recorded. Lastly, judgments of the three summary classifications are made. In the office, the pencilled notations on the field sheets are inked in, the mosaics are checked for omissions and inconsistencies, and border notations are co-ordinated with adjacent sheets.

One great advantage, especially, where urgency is given to land survey is that field personnel needs little training: it must be interested in the work, fully acquainted with the notation and skilled in the use of vertical aerial photographs. Field workers need be but few in number, although it is essential that they have the broadest possible outlook and training. In New Zealand adaptable men might be drawn from the Soil Survey Division and Plant Research Bureau of the Department of Scientific and Industrial Research and possibly from the Departments of Agriculture, Forestry and Lands and the honours geography school at Canterbury College. In parties of two, it is estimated that, under the variety of New Zealand geographic conditions, they could cover from 40–140 square miles a day.

THE CONTRIBUTIONS OF THE METHOD.

In New Zealand the results yielded by a nation-wide stocktaking undertaken on the unit area method would be of real value to a number of different agencies, both public and private. The data mapped would contribute materially to the solution of specific problems (soil erosion, noxious weeds), to rehabilitation and developmental programmes, to national and local administration (public works, taxation, catchment boards, etc.) and to manufacturing and commercial enterprises (stock and station agencies, commercial banks, dairy companies, etc.). From the completed maps and mosaics information of limited and specific kind can be readily abstracted. There are few Government departments which could not utilise the results of such a survey to the great advantage of the Dominion.

Only a selection of these many possible contributions can be touched on here. Three of the more outstanding of current domestic problems are to expand primary production, to rehabilitate returned servicemen and to counteract the growing menace of soil wastage. The unit area method of land classification contributes directly to their solution. It discovers and appraises the conditions under which accelerated erosion occurs and indicates its distribution. It measures the amount, quality and location of land which should be retired. It indicates, at the same time, the extent and distribution of areas suited to pioneer development, to resettlement and to closer occupance. It reveals where education, government assistance and demonstration might most readily expand production.

Its results touch few Departments of State more closely than the Department of Works, especially since that department is now responsible for the operation of the Soil Conservation and Rivers Control Act (1941). By indicating (more rapidly than any other survey method) the nature and extent of the soil erosion problem, the precise location of critical problem areas, the significance of many related and underlying factors, it furnishes the broad factual base on which an effective programme of soil conservation must be founded. The data provided indicate further those areas which, from the point of view of possible siltation as a result of rampant erosion, are unsuitable for the location of reservoirs or hydro-electric power sites; or again it reveals those areas in which erosion control must be inaugurated to protect existing dams from early siltation. The method may lend material aid in planning roading and railway projects. It

should help the State Forest Service to locate its inevitably enlarged planting programmes; the Education Department in planning school renewals or new buildings; the Land and Income Tax Department in more soundly apportioning taxes in rural communities, and the Department of Industries and Commerce in designing the location of new rural industries.

On a wider plane, the classification of land by the unit area method would indicate broadly, though with greater accuracy than hitherto, the population absorptive capacity of the Dominion's farm, station, and forest land. Most important, by recording the physical capabilities of land, it indicates where changing culture techniques might be most suitably and efficiently applied, so as to enable New Zealand's soil to contribute permanently and in the largest possible measure to the world's food supplies.

Conclusion: The Geographic Approach.

The unit area method of land classification employs an essentially geographic approach to land problems, for it focuses attention on the area or region as a unit of investigation and embraces a very wide group of phenomena—physical and cultural—in their association within the areal complex. Many scientific disciplines and technical agencies are concerned with land use and land planning. The former include economics, sociology, history, political science, botany, zoology and pedology; the latter include agencies dealing with specific and relatively narrow forms of land use such as agriculture, forestry, public works and town planning. There is in this situation a serious problem of integration and co-ordination, and an obvious danger of difficulties arising in land planning through narrowness of view and bias towards particular uses. Such was the experience in the United States under the variety of New Deal projects, and criticism of similar order can be fairly levelled against the small-scale land use survey and land planning projects undertaken in recent years in New Zealand. If, however, it is appreciated that planning consists largely of an investigation of the trends in land use within definite units of area and in directing these trends (rather than imposing some preconceived and possibly biassed pattern of use), the scientific basis of planning thus becomes the study of areas and of all the critical facts and relationships within them; and this requires the broadest possible approach. It is here that the geographic method and approach are of value. For a considerable period of time American, British, and continental geographers have been working on and experimenting with methods of regional land inventory (Joerg, 1935; Stamp, 1943). The present method of land survey and classification, though it may seem unique and novel to other specialist disciplines, is the outcome of a long series of experiments with techniques designed by geographers to facilitate land inventory. The unit area method provides a quantitative portrayal of the occupance pattern and is complete in areal coverage. In permitting, at the same time, a speed of operation not previously attained, considerable detail, and a high degree of accuracy, it contributes both to geography and to the multiplicity of the practical requirements of land planning.

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Vol. 74, Part 2, pp. 196–206, Plates 26–29.

The Gametophyte, Embryo and Developing Sporophyte of *Cardiomanes reniforme* (Forst.) Presl.

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INTRODUCTION.

IN a previous paper* the writer (Holloway, 1930) has described from cultures the earlier stages in the development of the gametophytes of *Hymenophyllum pulcherrimum* and of *Cardiomanes reniforme,* the latter under its old name *Trichomanes reniforme.* The gametophytes of the former species were then 3½ years old, but were only half-grown and did not bear sex organs. Those of *Cardiomanes* were considerably younger, but had advanced enough to make it seem probable that their further development would be along the lines of the *Hymenophyllum* ribbon and not of the *Trichomanes* branching filament.

These particular cultures were continued, that of *H. pulcherrimum* for a total period of 13 years, and that of *Cardiomanes* for a total of 6½ years. The present paper deals with the results obtained from the study of the latter.

All drawings (except those in figs. 3a, 5, and 35–37, which were plotted to scale) were made with the aid of an Abbé camera lucida. The gametophytes and embryos were sectioned throughout at 8 microns, and the sections were stained with Delafield's hæmatoxylin, combined in some cases with orange G. The drawings that illustrate the earlier stages in the embryogeny were checked against drawings made with the aid of an oil immersion objective.

THE GAMETOPHYTE.

(a) General Development.

Figs. 1–2 represent young ribbons after 12 months growth, Branching now commonly sets in, most of the gametophytes at 2 years taking the form of a tuft of elongating and widening ribbons growing more or less erect from the intact original procumbent region (figs. 3a and 3b). Later, by the decay of the basal region, these ribbons are set free as independent gametophytes. In among these tufts a number of gametophytes of an unusual, completely filamentous form were found. Fig. 4 shows one of these, taken when the culture was 3 years old. The further development of these is not known, but it is clear that the form of the gametophyte is very variable in its earlier stages of growth.

* By an error the magnification numbers of Figs. 14–21 in this paper (Holloway, 1930) were given at twice the correct size.

Both antheridia and archegonia appeared at or near the margins of the ribbons at 2½ years, when the latter were up to 7 millimetres in length. The antheridia soon became abundant, even on small ribbons, and were always more copious and widely scattered than the archegonia. The latter were confined to well-formed ribbons, and were in groups. The ribbons by this time had branched freely. After 6½ years growth they attained a length of 10–12 millimetres. Fig. 5 represents a well-grown, branching ribbon of typical form, bearing antheridia and archegonia, and also two young embryos on the hindermost branch.

On the culture gametophytes of *H. pulcherrimum* adventitious branches (gemmæ) occurred in great profusion in successive crops, and by becoming detached aided in the formation of a dense turf of ribbons. On the other hand the *Cardiomanes* gametophytes produced no gemmæ, although the cultural conditions were apparently identical in the two cases. The two cultures differed also in the fact that no antheridia were ever observed on the *Hymenophyllum* gametophytes although repeatedly searched for; however, on two occasions a cluster of a few sporelings was found.

(b) The structure of the ribbon.

Over the greater part of its area the *Cardiomanes* ribbon is one cell layer in thickness, with localised marginal archegonial cushions (Fig. 7). It thus corresponds in structure with that of *Hymenophyllum*. The sectioning of many ribbons, however, revealed that not infrequently there are small areas well away from the margins that are two-layered. These areas vary in size from single cells that have divided in the plane of the ribbon, to patches of several such cells, and to more extensive areas. Archegonia may be borne on the larger of these areas, on either one or both surfaces (Fig. 8) there being then a still further increase in the thickness of the area to form a cushion. The writer has found these two-layered areas in the culture gametophytes of *H. pulcherrimum* also.

The marginal cushions bear archegonia on one or on both surfaces (Fig. 7). The continued growth of these cushions, especially after fertilisation has taken place, commonly leads to an irregular shape and curving of the margin, with a consequent difficulty in orienting for sectioning the archegonia and the embryos that are present.

(c) The sex organs.

The development of the archegonium and of the antheridium was not followed. The mature archegonia (Fig. 9) have practically straight necks. The antheridium (Figs. 10–11) is considerably larger than that of typical leptosporangiate ferns. It corresponds with the antheridium of *Hymenophyllum* more closely than with that of *Trichomanes*. There is no cap cell, and there is a larger number of wall cells and of spermatocytes than in *Trichomanes*. The number of spermatocytes, as seen in a median vertical section of the antheridium, was found to be rather variable (*cf.* Figs. 10 and 11), in some cases being considerably greater than the number given by Bower for *Hymenophyllum* (1923, pp. 291–2).

Up to the age of 3½ years the cultures were watered only from below. Fertilisation was clearly thereby prevented, up to this point no embryos being observed, although both kinds of sex organs had been present on the ribbons for 12 months. At this stage of the culture the gametophytes were watered several times from above by thorough pipetting in order to induce fertilisation, with the result that it took place copiously. Within two months embryos were present in abundance.

The Embryo.

Over eighty embryos were studied in serial sections, ranging from the unsegmented fertilised egg up to the stage at which the cotyledon and primary root are elongating (Fig. 6). Since, according to the most recent accounts of the family, e.g., Smith (1938, p. 319), the embryogeny has hitherto not been known at all in any member of the Hymenophyllaceae, a somewhat detailed account will now be given of it in Cardiomanes. The features of especial significance for the purpose of comparison with the embryo of other Filicineae are the position of the first or basal wall, and the time and place of origin of the main body organs.

(a) The early developmental stages.

A considerable number of fertilised eggs were met with in the sections (Fig. 7). In determining the precise direction of the first or basal wall in the segmenting zygote it is necessary to visualise this wall in its relation to the embryo in its entirety, and not merely as seen in the plane in which the embryo happens to be cut. In the plane of sectioning the basal wall may appear in a single section to be transverse to the axis of the archegonium, whereas it may actually be inclined in the longitudinal plane at right angles to this, and thus must be described as an inclined wall. The behaviour of this wall in this latter plane can be ascertained by noting its position in the embryo in the successive sections of the series, when, if it is inclined in this plane, its position will be found to change from section to section. Figs. 12a–c illustrate three successive and more or less median longitudinal sections of a 2-celled embryo, in each of which the basal wall appears as transverse, whereas a comparison of the three figures shows that it is actually slightly inclined. Altogether seven 2-celled embryos were examined, and eight that were 3–6 celled as seen in median longitudinal view. In some of these the basal wall was found to be strictly transverse as observed in the two longitudinal planes, whereas in others it was more or less inclined. In none of them could it be described as truly vertical such as it is in the typical leptosporangiate ferns. In Figs. 13–14 are illustrated two 2-celled embryos in which the wall has a greater or less degree of inclintion. That shown in Fig. 14, in which the inclination was the greatest that was observed, was situated on the opposite side of the same cushion as that shown in Fig. 12. Thus in *Cardiomanes* the basal wall can in general be stated to be more or less transverse to the longitudinal axis of the archegonium, a point that is of importance in comparing the embryo of the Hymenophyllaceae with that of other Filicineae.

The epibasal and the hypobasal cells next subdivide, either of them being the first to do so (Figs. 15–16), to form an embryo that is 4-celled as seen in median longitudinal view (Figs. 18–19). Two abnormal examples of a 3-celled embryo were found, one of these (Fig. 16) being of a " giant " nature, and the other (Fig. 17) having undergone two successive transverse divisions. Comparison of the two embryos in Figs. 20–21 indicates that there is no regularity in the sequence of cell divisions that immediately follow. The outline of the hypobasal portion of the second of these embryos indicates that it has been cut somewhat obliquely. Eleven embryos of about the same size as the three shown in Figs. 22–24 were sectioned, and in none of them did a careful scrutiny of the entire series of sections reveal any cells that could be interpreted as apical cells. It would be very difficult to recognise apical cells as such for certain until they have begun to segment, unless, as in the case of the advanced type of leptosporangiate embryo, they originate at a fairly definite and early stage in the embryogeny. The size of the embryos illustrated in Figs. 22–24 can be held to show that in *Cardiomanes* the cotyledon and the other body organs are set apart relatively late.

(b) The origin of the main body organs.

It has already been stated that difficulty was experienced in orienting the embryos for sectioning. Not only do the marginal cushions usually curve over irregularly, but also, on account of the varying position of the basal wall, the cotyledon and root apices have no constant position relative to the neck of the parent archegonium or to the longitudinal direction of the gametophyte ribbon. Thus to obtain median sections of a globular embryo that show the origin of its growing points is a matter of chance.

Nine embryos were sectioned in which the apical cell of the cotyledon alone was present. The three that have been selected for illustration (Figs. 25–27) indicate the size of the embryo at this stage. Figs. 25 a–b represent two consecutive sections through an embryo in which the cotyledon apical, which appears in Fig. 25a cut somewhat obliquely, has just begun to segment. Figs. 26 a–b represent two non-consecutive sections of an embryo of an extra large build, at a similar stage. Fig. 26a shows the full size of its epibasal region and the presence of the cotyledon apical cell, and Fig. 26b shows the full size of the hypobasal region. In Fig. 27a the cotyledon is at a slightly later stage of development as indicated by the arrangement of the cells at this point. The original basal wall is clearly to be seen in Figs. 26–27, as also in the earlier Figs. 22 and 24, lying more or less transversely to the direction of the neck of the archegonium.

In these three embryos it was doubtful whether or not the apical cell of the primary root had as yet been set apart. No indication of such an apical was found in the embryo shown in Fig. 26. In Fig. 25 the rather symmetrical arrangement of the cells around the one marked X may possibly indicate that the latter is the apical cell of the root in an endogenous position and cut transversely. Fig. 27b represents one of the series of sections through the embryo shown in Fig 27a, on the opposite side of the epibasal region to the cotyledon, cut below the surface. Here also it is possible to interpret

the cell marked X as a segmenting root apical cut more or less transversely. On the whole, however, it may be concluded that the root originates a little later than the cotyledon.

Figs. 28 a–b are two non-consecutive sections of an embryo that has developed a little further than those just described. The position of the original basal wall is not clear. The apical cells of both cotyledon and root have cut off several segments, the cotyledon being somewhat more advanced in growth than the root. A cell at the base of the cotyledon away from the position of the root may be interpreted as the stem apical. In older embryos (e.g., Fig. 32) the position of the stem apex is always clearly indicated by overlapping hairs, and in this particular case young hair-like protrusions of surface cells were to be seen immediately below the stem apical. Thus in this embryo, the cotyledon, stem and root all come from the region that lies nearest to the archegonium neck. If it can be assumed that in this embryo the basal wall was transverse or only slightly inclined, it would follow that the three organs originate from the epibasal region, the hypobasal region constituting the foot. The present study, however, has not succeeded in determining precisely the point of origin of these organs.

In the embryo shown in Fig. 29 the root apex points directly towards the neck of the archegonium, the basal wall having been probably strongly inclined. The root is apparently endogenous in origin. Fig. 30a is a general view of an embryo similar to the last. The cotyledon and stem apices are cut medianly and are shown in greater detail in Fig. 30b. In Fig. 30a the dotted line separates the large-celled region of the embryo from that which bears the three growing points. The position of the root apex which appeared in another section cut obliquely, is indicated by an X. Figs. 31 a–b are two consecutive transverse sections through the apical cell of the root at about this age, showing its form and mode of segmentation. Figs. 32 a–b are two consecutive sections of another embryo in which the stem apical has commenced to segment. Here, as in Fig. 29, the root apex seems to be endogenous.

A number of embryos were sectioned illustrating the succeeding stages of growth. The elongation of cotyledon and root in opposite directions (Figs. 34 and 6) is at first fairly fast as shown by observation of the cultures, but further growth is very slow. The cotyledon remains in alignment with the root, usually without any curvature. As in other ferns the stem is from the first especially slow in developing. Its conducting strand is formed later than that which connects cotyledon and root, and joins up laterally with this.

Considering the slender nature of the *Cardiomanes* gametophyte, it was surprising to find how many of them bore a plurality of embryos. In one case there were as many as seven on one ribbon. There were several cases of two, and one of three well grown embryos on the same cushion. It was noticeable that starch frequently accumulates in and around a half-grown embryo. The foot is large, but in the older embryos it tends to be in direct contact with the cushion only at its base, so that these embryos project strongly (Figs. 34 and 6).

THE DEVELOPING SPOROPHYTE.

The following account is based upon the study of a large number of sporelings obtained from the cultures and, in the case of the later stages, from several forest localities. They have provided a continuous developmental series in stem and frond form and structure. The most advanced of the culture sporelings were about 3 years old, and bore on a short, erect stem 4 or 5 linear fronds up to ¾ inch long. The youngest of the field sporelings were similar to these, those that were older bearing on the primary erect stem and the subsequent young rhizome fronds that showed a progressive transition from a linear to a lobed form, and finally to a form closely comparable with the characteristic reniform frond of the mature sporophyte.

(a) The form and mode of growth of the frond.

The growth of the cotyledon is altogether apical, but the mode of its growth passes through several distinct changes. It at first elongates as a cylindrical organ without lamina wings. Early in this stage the original apical cell changes to one of a dome-shaped form by the progressive flattening of its cutting faces, so that it now segments by walls parallel to its flat base (Fig. 33). Next, narrow one-layered lamina wings begin to develop at the apex owing to the dome-shaped apical changing to one of a wedge-shaped form with two cutting faces. The actual origin of this change was not observed. When the cotyledon is a few millimetres long its apex becomes occupied by a marginal series of segmenting cells which divide anticlinally and periclinally, the lamina wings now progressively increasing in width. In his study of frond rudiments of the mature sporophyte of *Cardiomanes,* Bower (1889, p. 331) describes the transition from a single wedge-shaped apical to a marginal series as taking place by a T division of the former. The cotyledon preserves the linear form, but occasionally exhibits a weak single forking which was observed to originate as a true dichotomy of the apex.

The fronds next formed either remain of a simple linear form or are once forked. In tracing the ontogenetic sequence in frond form in the field sporelings comparison will be made between fronds that are fully grown, such a condition being indicated by the complete cessation of cell-divisions in front of the vein tips. The fronds that succeed show a progressively greater extent of vein-forking accompanied by lobing of the forward region of the lamina (Figs. 35–36). As they succeed one another this lobing becomes more symmetrical (Fig. 36), then it becomes less pronounced (Fig. 35), until finally it is completely absent (Fig. 37). Fronds with a continuous, unlobed lamina show no lobing at any stage of their growth. From this point in the ontogeny, all succeeding young fronds take the form of an elongated petiole terminating in a very small entire lamina which increases in extent by growth all around the margin of the forward part.

Reference must also be made to the growing points during this sequence. Where lobing is present, meristematic activity remains apical, the several growing points being thus well separated. In the later fronds the progressive elimination of lobing, together with the increasing number of dichotomies of the growing points, brings

it about that the latter remain in progressively closer juxtaposition to one another. They are placed around the periphery of the forward region of the lamina, the margin of the hinder cuneate region consisting of permanent tissue.

In Fig. 37 is represented a half-grown unlobed frond from a sporeling rhizome. The finely crenulate forward margin is occupied by a considerable number of closely spaced growing points, each lying in a shallow sinus in front of a vein-tip. With the increase in size of such a frond the growing points undergo further dichotomies with the result that thy come to lie so close together as to be practically continuous. In subsequent fronds dichotomies of the growing points follow one another in quick succession as soon as the lamina begins to form at the tip of the petiole. The hinder cuneate region of the lamina thus becomes less well developed, and the strong growth of the forward region leads to the well-known reniform shape of the frond as a whole.

(b) The structure of the lamina.

In the Hymenophyllaceae the lamina of the frond of the mature sporophyte is typically one cell-layer thick. Certain exceptions to this are known, the several-layered lamina of *Cardiomanes* and of *H. dilatatum* being well-known cases. Bower (1889, p. 342) states that in some other species the lamina is several-layered near the veins.

The sporelings of *Cardiomanes* afforded an opportunity for tracing the manner of origin of this several-layered condition and of certain other features of interest. In the upper part of an occasional well-grown cotyledon, the vein is flanked on both sides by a narrow several-layered belt of lamina tissue of irregular width. This belt is readily distinguished in surface view, sections showing that it is a 3-layered extension outwards of the parenchyma that surrounds the vein. In the fronds that immediately follow this belt is a usual feature, and is somewhat wider in extent. Fig. 38 represents a transverse section of such a frond where the belt is present on one flank of the vein, but absent on the other. In fronds that are beginning to show " webbing " of the lamina lobes the 3-layered condition progressively extends over that part of the lamina that lies between the veins, from the hinder part of the frond forward into the lobes, following each vein towards its tip as a narrowing belt (Fig. 36). Fig. 39 shows in section this extension taking place at the point indicated on the frond in Fig. 36. Finally, in completely webbed fronds, the condition is reached in which the entire lamina is 3-layered except for a continuous marginal zone. In the forward region of such a frond this zone is very narrow (Figs. 37 and 40), lying beyond the position of the vein endings, but it widens out in the hinder cuneate region. Thus the several-layered structure originates in the neighbourhood of the veins, and extends progressively outwards from these by cell-divisions taking place in lamina tissue that had previously been inactive.

For the purpose of comparison, the writer has examined the frond structure in all the New Zealand species of *Hymenophyllum* and of *Trichomanes* and has found that, in addition to *Cardiomanes*,

only *H. dilatatum* and *H. scabrum* show any departure from the one-layered condition of the lamina. Field sporelings of each of these two species were available for study. The several-layered condition of the lamina originates in the sporeling frond, at a late stage in the ontogeny of *H. scabrum* but much earlier in *H. dilatatum,* in precisely the same way as in the sporeling of *Cardiomanes,* viz., as a 3-layered belt of irregular width flanking the veins of the frond segments. In progressively later fronds it extends outwards until in *H. dilatatum,* but not invariably in *H. scabrum,* it reaches to the margins.

In tracing still further the ontogenetic sequence in frond structure in *Cardiomanes,* it was found that in the entire fronds that next arise on the young rhizome a modification of the mode of segmentation of the marginal cells sets in that results in the formation of a strengthening rib around the forward part of the frond periphery. Fig. 41 shows the actual origin of this in a young frond, and Fig. 42 shows the extent to which the rib has developed by the time such a frond is fully grown. With the inception of the rib further extension in the size of the lamina is restricted to intercalary cell-divisions in the zone within the margin.

The marginal rib is a prominent feature of the frond of the mature sporophyte (Fig. 43). In sterile fronds it is continuous around the lamina to its base. In fertile fronds it is present at the places where sori are absent. There is a well-defined cuticle over the rib surface, the lamina cuticle being more delicate even on old fronds. The lamina is several-layered right up to the rib, the number of layers finally becoming four by the subdivision of the central large-celled layer.

The youngest fronds examined of mature sporophytes, in which the lamina was still very small, were found to possess a fairly well-formed rib. Bower states with a figure (1889, p. 344 and Fig. 51) that the "young" frond of the well-grown sporophyte of *Cardiomanes* has a marginal series of hemispherical segmenting cells whose segments almost immediately subdivide to form a several-layered lamina. He does not mention the marginal rib. The present writer did not observe the condition described by Bower, probably because it occurs only in the lamina while still circinnately inrolled. Such a condition would be comparable with that which is present at a much earlier stage in the ontogeny. A marginal series of this type is a characteristic feature of the Hymenophyllaceae, but is only transitory in *Cardiomanes.*

The rib is no doubt of importance in preventing tearing of the broad lamina. It is well known that *Cardiomanes* can occur in more or less exposed positions, and that under dry conditions the lamina inrolls strongly from both sides.

(c) The stem stele.

On the short, erect primary stem of the sporeling the phyllotaxy is spiral. With the sideways curvature of the stem apex to give the horizontal rhizome the fronds become more widely spaced apart, and are borne laterally along the two sides of the rhizome, so that the latter is dorsiventral in habit.

In the sporeling erect stem the stele is a typical protostele, with a central solid mass of tracheids surrounded by phloem and pericycle (Fig. 44). As seen in transverse section the protoxylem is not distinguishable. Fig. 45 shows the appearance of the stele of an erect stem at the point of departure of a frond trace, it being evident that the stele is undergoing a more or less equal dichotomy. The inception of forking is indicated by the oval form of the stele as a whole, the interruption of the phloem ring, and the presence of parenchyma breaking across the xylem mass.

In the horizontal rhizome there is a distinct and sudden change in stelar form. This is illustrated in Fig. 46, which represents the stele of a very young rhizome about 5 millimeters long, on which no fronds had as yet become apparent. The ring of phloem is well developed, but the tracheids are few in number, those placed centrally probably being the protoxylem. After further growth the rhizome stele begins to show an arrangement of the tracheids comparable with the two-banded arrangement in the mature rhizome. In Fig. 47 is shown the stele of a rhizome that was 4 centimetres in length and bore several fronds, the section being taken about halfway along the rhizome. The metaxylem takes the form of an upper and a lower band, with the protoxylem in a central position embedded in parenchyma. Boodle (1900) has described and figured the stele of the mature rhizome of *Cardiomanes* and of various other members of the family. He states that in the larger species of *Hymenophyllum* and in *Cardiomanes* the frond and root traces come off from the ends of the xylem bands at the two lateral lines, and that there are no leaf gaps. The rhizome stele is thus of protostelic nature, although of a modified form.

Discussion.

In his account of the Hymenophyllaceae Bower (1926, p. 248) has set out the arguments in favour of regarding this family as "relatively primitive," while showing features of specialisation to a hygrophilous habit particularly along the lines of reduction. He regards *Cardiomanes,* together with certain large species of *Hymenophyllum,* as on the whole best representing the ancient stock of the family. It remains now to discuss briefly certain features in the life history of *Cardiomanes,* described in the present paper, in connection with these views.

The gametophyte is of the *Hymenophyllum* ribbon type. The altogether filamentous gametophyte characteristic of *Trichomanes* is commonly regarded as being much specialised, so that in accordance with this view *Cardiomanes* and *Hymenophyllum* have retained a more primitive form. Bower, however, (1923, p. 294) expresses a less decided view as to which of these types is the ancestral one, holding it to be tenable that the ribbon is the derived form. At the same time he considers that the filicinean gametophyte does not provide sufficiently trustworthy material for phyletic argument. In the form of its gametophyte *Cardiomanes* stands nearer to *Hymenophyllum* than to *Trichomanes.* It may be held that since this similarity involves a number of distinct points of detail it is more likely to be due to affinity than to homoplasy.

The antheridium is more like that of *Hymenophyllum* than of *Trichomanes,* in its general size, the relatively large number of wall cells and of spermatocytes, and in the absence of a cap cell. The antheridium of *Hymenophyllum* shows a closer similarity with that of such ancient forms as *Osmunda* and *Gleichenia* than with that of the advanced Leptosporangiatae. That this represents in the Hymenophyllaceae a persisting ancient feature is emphasised by the fact that in the *Cardiomanes* antheridium there is an even larger number of spermatocytes than in that of *Hymenophyllum.*

In the embryogeny of *Cardiomanes* primitive features are especially in evidence. The first or basal wall is more or less transverse to the longitudinal axis of the archegonium as in certain eusporangiate ferns, and not parallel with it as is usual in the leptosporangiates. This is remarkable, since even such ancient leptosporangiates as *Osmunda* and *Gleichenia* have the latter type of embryo segmentation. La Motte (1937, p. 702) has shown that in the very young embryo of *Isoetes* the position of the basal wall can experimentally be made to change in response to changes in the direction of the gravitational stimulus. In *Cardiomanes* the basal wall varies somewhat in position. It is possible that this may be due to variation in the position of the young embryo with respect to the direction of the gravitational stimulus, since the archegonia are not oriented in any fixed position. Even if such be the case, the fact still holds that a considerable number of young embryos were studied in all of which the basal wall was more or less transverse.

In the relatively late differentiation of the main body organs the embryo of *Cardiomanes* corresponds with that of the eusporangiate ferns and of *Osmunda,* and not with that of the advanced leptosporangiates. It preserves a globular form for a considerable time, and is a fairly massive body by the time the cotyledon is set apart. The primary root apparently arises endogenously, as in the more ancient fern types. On account of the varying position of the basal wall it has not been possible to determine definitely from which region of the two-celled embryo the several body organs are derived, but in the opinion of the writer the cotyledon, primary root and stem all come from the epibasal cell, i.e., the cell nearest to the archegonial neck, the hypobasal cell forming only the foot. The developmental stages figured, with the exception of the earliest, correspond very closely with those figured by Cross (1931) for *Osmunda cinnamomea.*

The sporeling possesses, at some or other stage in its development, such frond features, usual in the family, as the more or less dissected form, the one-layered lamina, and a marginal series of cells that segment in the manner characteristic of the Hymenophyllaceae. These features become progressively replaced by others that finally lead to the very specialised frond of the mature sporophyte. Thus with respect to these features *Cardiomanes* provides a good illustration of the doctrine of recapitulation. Bower (1926, p. 238) has stated the view that the occurrence of a several-layered structure of the lamina in *Cardiomanes* does not represent the persistence in this genus of an ancestral character, but rather a tertiary return to it. The ontogenetic facts can be held to substantiate this

view. It is noteworthy that two other members of the family, namely, *H. dilatatum* and *H. scabrum* are similar to *Cardiomanes* both in the possession of a several-layered lamina and in the manner of its origin.

The typical protostele of the erect primary stem must also be referred to. It is well known that in many ferns in which the mature stele is of a relatively complex form, there is an initial protostelic stage which is regarded by Bower (1923, chap. 7) as a persisting primitive feature. There can be no doubt that the *Cardiomanes* sporeling does recapitulate certain frond characters that are typical of the family, but absent from its own adult frond. Such frond characters are thus ancestral for *Cardiomanes*. It is possible to regard the protostele of its erect stem as a persisting type of stele that originally gave rise to the various modifications that Boodle has described (1900) in different members of the family. The evidence of recapitulation, however, is not so cogent here as in the case of the frond characters referred to.

Thus certain facts with regard to the life history of *Cardiomanes* are in accordance with the view that the Hymenophyllaceae is a relatively primitive family. The structure of the antheridium, possibly also the primary protostele, and especially the embryogeny, bear this out. It remains to be seen whether or not other members of the family have the same type of embryo. It appears that *Cardiomanes* has closer affinities with *Hymenophyllum* than with *Trichomanes* with respect to the type of gametophyte and the structure of the antheridium, as well as with respect to the number of spores per sporangium and the stele of the mature stem as other writers have shown. At the same time it has developed specialised frond characters that enable it to withstand drier conditions than those usual for the family, these characters having developed in a frond that at an earlier period showed the same type of specialisation in frond-lamina structure as has the family as a whole.

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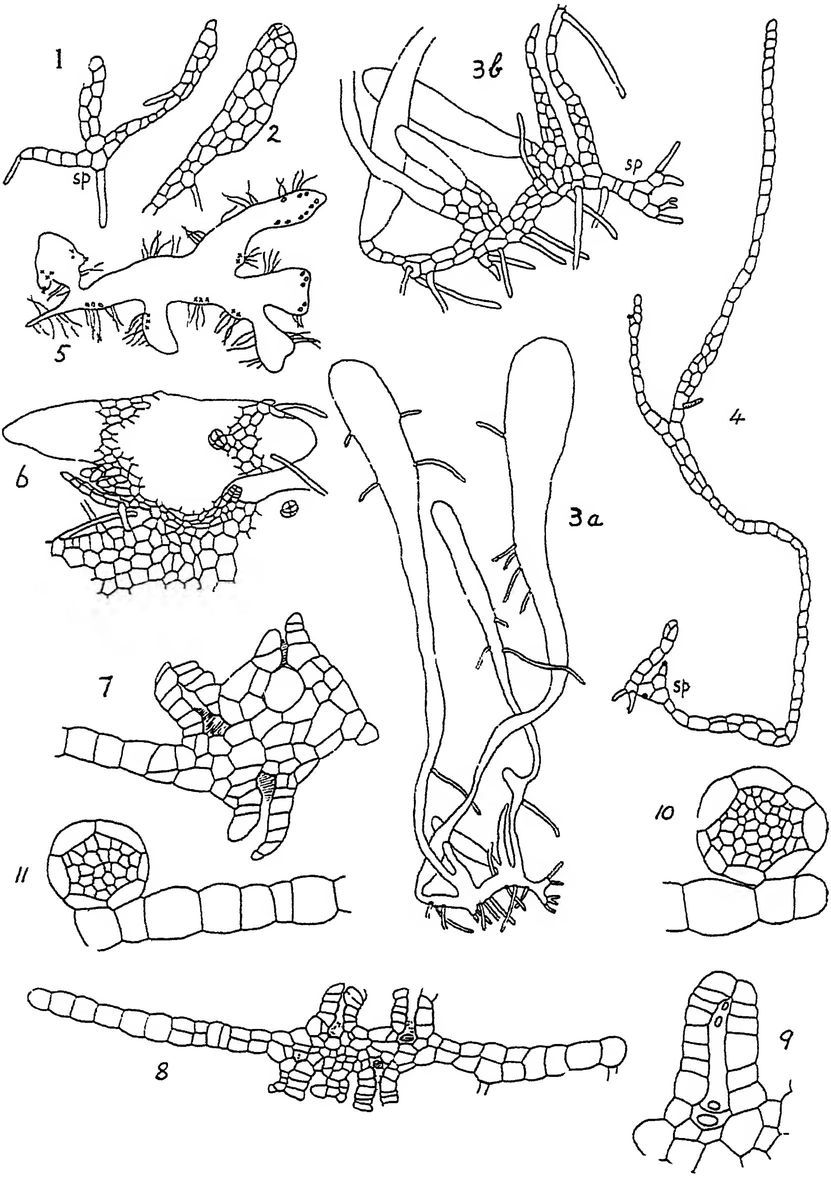

Figs. 1–11.—The gametophyte of *Cardiomanes*. Figs. 1–2.—Early setting in of the ribbon habit, x40. Fig. 3a.—Tufted form at 2 years, x17. Fig. 3b.—Basal region of the same, x40. Fig. 4.—Unusual filamentous form, x40. Fig. 5.—Typical ribbon at 6½ years, x5. Fig. 6.—Surface view of a marginal cushion bearing a well-grown embryo, x40. Fig. 7.—Vert. sect. across a marginal cushion, x120. Fig. 8.—Vert. sect. across a ribbon showing a centrally-placed cushion, x80. Fig. 9.—A mature archegonium, x160. Figs. 10–11.—Two mature antheridia in median vert. sect., x160.

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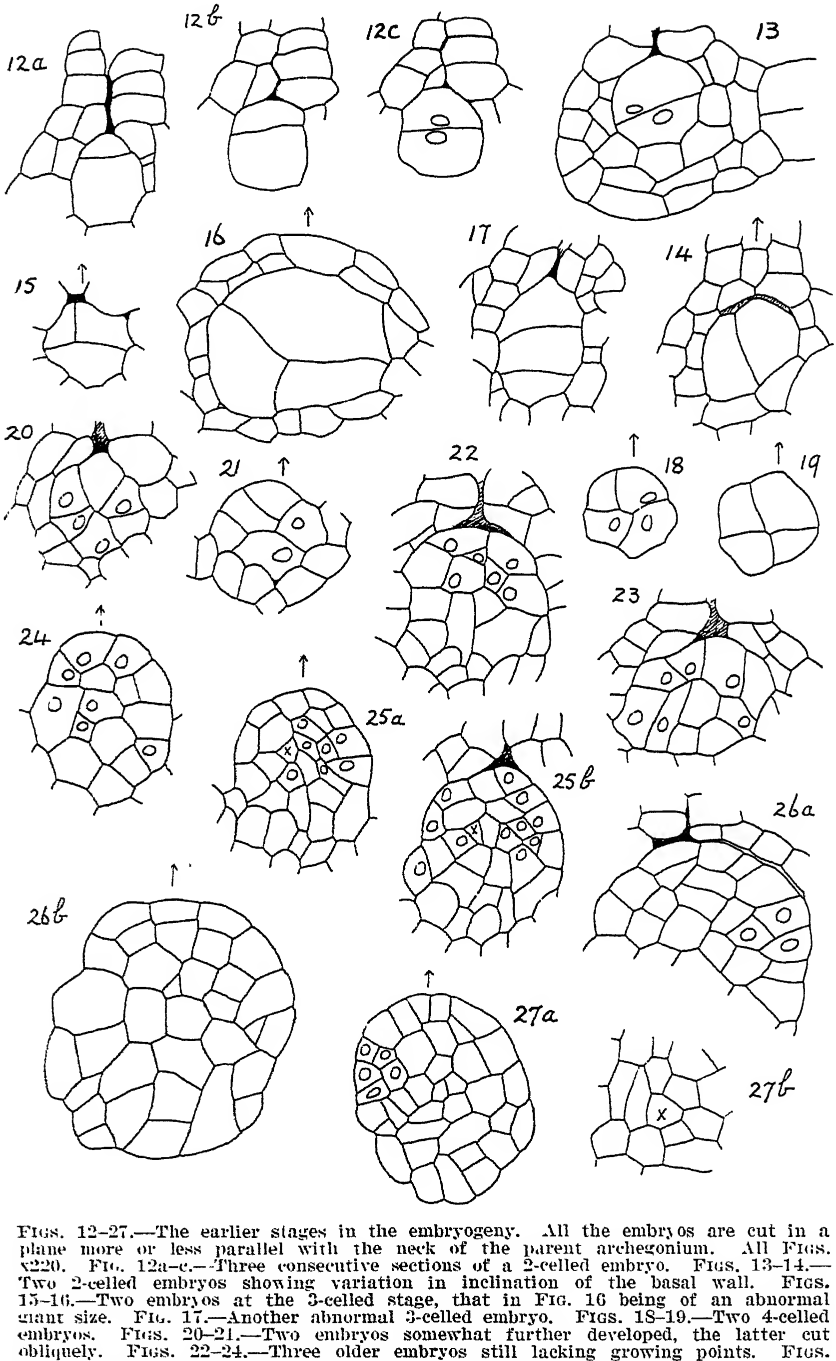
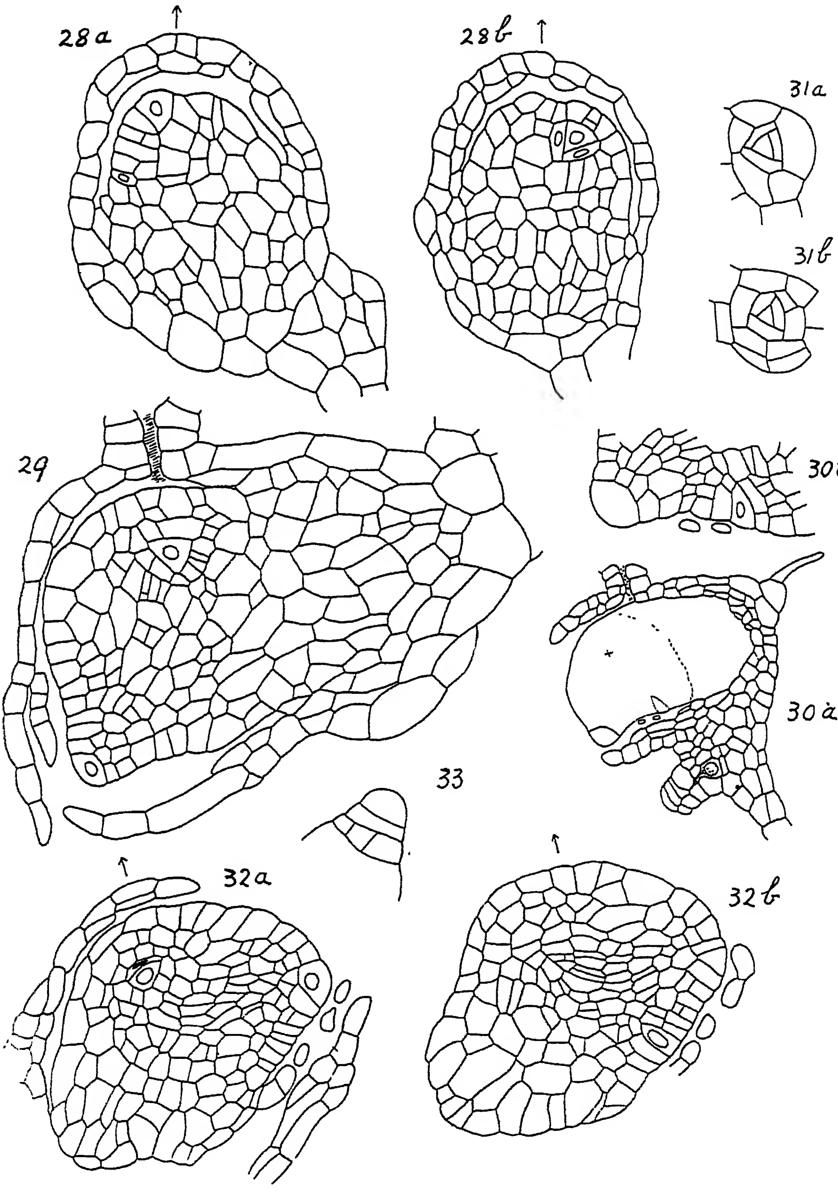


FIGS. 12–27.—The earlier stages in the embryogeny. All the embryos are cut in a plane more or less parallel with the neck of the parent archegonium. All FIGS. ×220. FIG. 12a–c.—Three consecutive sections of a 2-celled embryo. FIGS. 13–14.—Two 2-celled embryos showing variation in inclination of the basal wall. FIGS. 15–16.—Two embryos at the 3-celled stage, that in FIG. 16 being of an abnormal giant size. FIG. 17.—Another abnormal 3-celled embryo. FIGS. 18–19.—Two 4-celled embryos. FIGS. 20–21.—Two embryos somewhat further developed, the latter cut obliquely. FIGS. 22–24.—Three older embryos still lacking growing points. FIGS. 25–27.—Three embryos in which the cotyledon apical has been set apart: FIGS. 25a–b are consecutive sections, but FIGS. 26a–b and also FIGS. 27a–b are not consecutive; the cell marked x in FIGS. 25 and 27 may possibly be the root apical.



FIGS. 28–33.—Later stages in the embryogeny. All FIGS. (except 30a) x175. FIGS. 28a–b.—Two non-consecutive sections of an embryo showing the cotyledon, root, and young stem apicals. FIG. 29.—Embryo with cotyledon and root apices further advanced, the latter being apparently endogenous. FIG. 30a–b.—A similar embryo: FIG. 30a in general view x88: FIG. 30b, details of cotyledon and stem apices. FIG. 31a–b.—Two consecutive trans. sects. through a root apical at this age. FIG. 32a–b.—Two consecutive sections of an embryo showing the position of the three apicals, the root is apparently endogenous. FIG. 33.—The dome-shaped apical cell of the cotyledon at a still later stage.

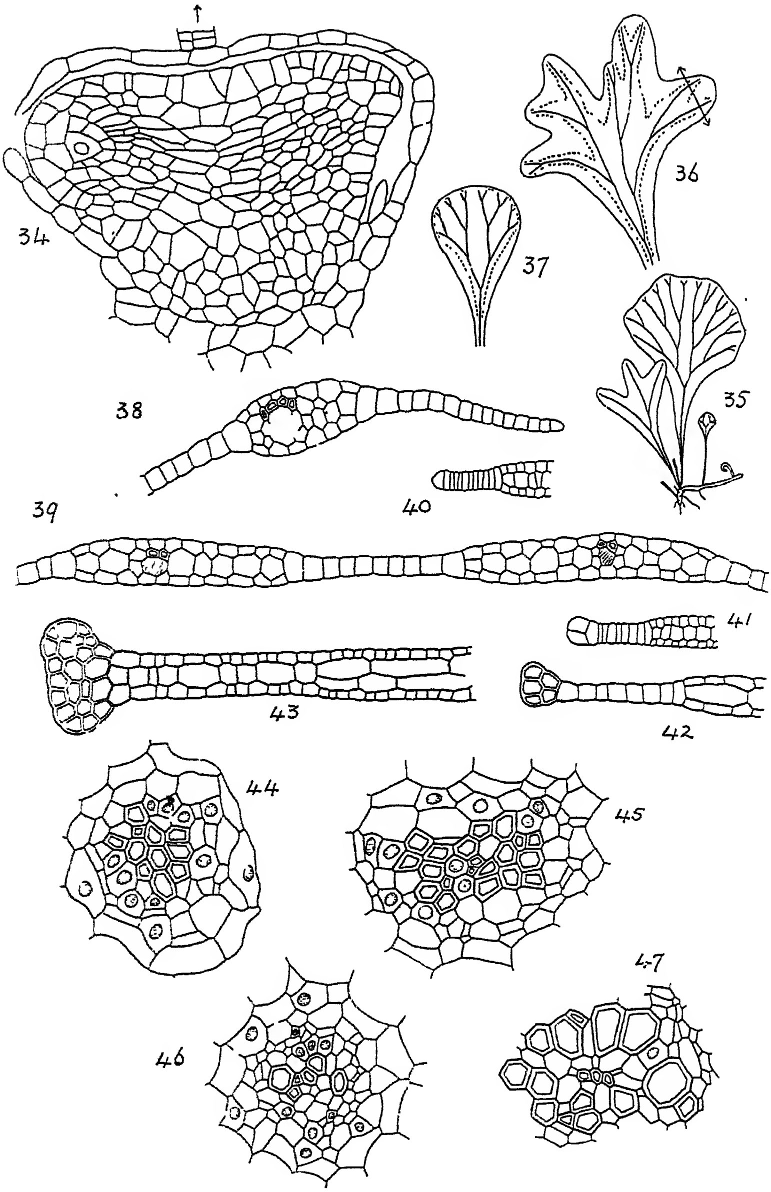


FIG. 34.—Embryo showing elongation of both cotyledon and root, x150. FIG. 35.—A sporeling showing erect primary stem and young rhizome, with sequence in frond-form, nat. size. FIG. 36.—A lobed sporeling-frond showing outline (dotted) of 3-layered region of the lamina, x2. FIG. 37.—A young entire sporeling-frond showing outline (dotted) of 3-layered region, x2. FIG. 38.—Vert. sect. across a linear sporeling-frond showing several-layered belt of lamina on one side of the vein, x57. FIG. 39.—Vert. sect. across a lobe of the frond in FIG. 36, at the place marked, showing extension of the 3-layered region outwards from the veins, x57. FIG. 40.—Vert. sect. across margin of the forward region of the frond in fig. 37 showing marginal growth and extent of the one-layered region, x57. FIGS. 41–42.—Vert. sects. across margin of forward part of a later entire sporeling-frond, when young and when fully grown respectively, showing formation of marginal rib, x57. FIG. 43.—Vert. sect. across margin of a well-grown sterile frond of a mature sporophyte, showing full size of marginal rib and absence of a one-layered region, x57. FIG. 44.—Trans. sect. of the protostele of the erect stem of a sporeling, x365. FIG. 45.—Trans. sect. of the protostele of the erect stem of a sporeling at the point of departure of a frond trace, x365. FIG. 46.—Trans. sect. of the modified protostele of a very young sporeling rhizome, x365. FIG. 47.—Trans. sect. of the xylem region of the modified

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Molluscan Evidence of Pliocene Climatic Change in New Zealand.

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Abstract.

Faunal changes in the New Zealand Pliocene suggest that late Tertiary lowering of sea temperatures reached its peak in the mid Pliocene, when sub-antarctic water extended northwards to Southern Hawke's Bay, bringing a characteristic cold water fauna. In the upper Pliocene, further advance of cold water isotherms was prevented by a new factor, the Notonectian subtropical current, which has continued to affect New Zealand coasts, bringing a fauna of East Australian warm-water molluscs, and driving sub-antarctic waters and their fauna south to their present position. New Zealand mollusca did not suffer changes commensurate with the severity of the Pleistocene glaciation. This anomaly may be due to the persistence of the warm current influence through the Pleistocene, so that the low air temperatures of the Glacial Period failed to affect the marine fauna.

Introduction.

Students of the Tertiary mollusca of New Zealand have made a number of generalisations concerning the trends and events in the development of the present fauna. The chief of these are:—

(1) The evolution of an autochthonous element, the ancestors of which were already in the New Zealand area in early Tertiary or even late Cretaceous times (Marshall, 1919, etc.; Marshall and Murdoch, 1920, p. 125; Finlay, 1925, p. 163).

(2) The reinforcement of such a fauna by Indo-Pacific and possibly other elements during the Tertiary (Marwick, 1925, p. 376, 1926 A, p. 272) and particularly during the early half of the Tertiary (Marwick, 1929; Finlay and Marwick, 1940, p. 129).

(3) The extinction of mid-Tertiary genera in the Miocene and early Pliocene (Marshall and Murdoch, 1920; Powell, 1931, p. 90; Laws, 1936; Finlay and Marwick, 1940).

(4) The sudden immigration of species of East Australian origin in the latest Pliocene, which has continued in Recent times (Finlay, 1924, 1925, 1926, 1931, etc.; Finlay and Marwick, 1940; Powell, 1927).

There has been general agreement (Marshall and Murdoch, 1920; Powell, 1931; Laws, 1936; Finlay and Marwick, 1940, p. 129) that the post mid-Miocene extinctions were due in large part to cooling seas, and that such cooling was part of the onset of world-wide refrigeration which culminated in the Pleistocene glaciation. Many of the genera and families which suffered extinction are now confined to tropical and subtropical seas (*Cucullaea, Isognomon, Pteria, Spondylus, Pyrazus, Morum, Galeodea, Conospirus, Olivella,* etc., etc.). Comparison of the Recent ranges of such molluscan groups with the distribution of the surface waters of the world to-day (Schott, 1935; Deacon, 1933, 1936) leads to the conclusion that New Zealand, in the mid-Miocene, lay wholly within seas with the thermal

and other characteristics of the present Sub-tropical Zone of surface waters. There is no latitudinal zoning in the Miocene faunas to suggest, for instance, that the Miocene seas at Clifden, Southland, were appreciably cooler than those at Kaipara, North Auckland, so that, if a hydrological regime comparable to the present existed in the Miocene, the Sub-tropical Convergence must have been well to the south of New Zealand. At the same time, the apparent absence of reef building corals throughout the New Zealand Tertiary would seem to place an upper limit in any assessment of Miocene sea temperatures.

The progressive extinction of Miocene genera culminated in the Waitotaran Stage of the Lower Pliocene, which contains a number of lingerers from Miocene time, and they, with other features of the Waitotaran fauna of Taranaki (Marshall and Murdoch, 1920; Powell, 1931) point to hydrological conditions still warmer than at present. From the Nukumaruan until Recent times the generic extinctions are much fewer, and Hutton (1872) concluded that there was no difference other than what can be ascribed to passage of time between the Upper Pliocene and Recent mollusca. "He contended that the Wanganuian molluscan fauna . . . was so like that of present seas that no important lowering of temperature could have intervened" (Marwick, 1926 B, p. 1771). Hutton (1872; 1904, p. 18) therefore advocated a Lower Pliocene age for the glacial epoch in New Zealand. Subsequent study has confirmed the close relationship between Upper Pliocene and Recent faunas, so that it is inconceivable that a lowering of sea temperatures of as much as 4°–5° C., such as is suggested to have occurred during the Pleistocene in other parts of the Pacific (Davis, 1928, p. 219), can have taken place in the New Zealand Pleistocene. A change of such magnitude might reasonably be expected to show itself in more pronounced faunal differences than those between the Castlecliffian and Recent faunas.

The abundant geomorphic evidence that the glacial epoch in New Zealand was Pleistocene (i.e., post Castlecliffian) and not Pliocene (as the above considerations tend to indicate) will not be summarised here. Some of the evidence relative to the problem was presented by Marwick (1926). The problem is complicated by the fact that in none of the heavily glaciated areas of New Zealand have Castlecliffian marine sediments been involved in the movements which initiated the geomorphic cycle in which glaciation was an important episode; on the other hand, mountain ranges, the elevation of which has been subsequent to the deposition of Castlecliffian sediments (Ruahine-Tararua-Kaikoura), show few evidences of glaciation, though it is probable that such occur and await fuller description (Adkin, 1912; Rose, 1933). The lengthy post-Waitotaran history postulated by Wellman and Willett (1942, pp. 304–5) from their studies of the structure and geomorphology of the western Alpine region, makes it improbable that the glaciation could have been Nukumaruan or Castlecliffian, while, on the eastern flanks of the glaciated alps, Speight (1934, 1942) has shown that glacial deposits long post-date the Kowhai Series for which Mason (1941, p. 124) has quoted a Waitotaran-Nukumaruan fauna; the partly coeval

Bourne sandstones and conglomerates of the north (Fyfe and Healy, 1935, p. 10) contain faunas possibly as high as Castlecliffian. All told there is little doubt of the post-Castlecliffian age of the glaciation.

In reconstructing Pliocene and Pleistocene climatic trends, the failure of the palaeontological and geomorphic evidence to synchronise constitutes an anomaly demanding explanation. It is the purpose of this paper to furnish data on the hydrological implication of some Pliocene faunal changes, and to put forward an hypothesis which might reconcile the anomalies stated above.

A Nukumaruan Cold Water Faunal Immigration.

In the Waitotaran and Lower Nukumaruan Stages of the New Zealand Pliocene the extinction of warm water mid-Tertiary genera was accompanied by a northward immigration of a number of molluscs of southern cold water origin into the middle North Island; in the Upper Nukumaruan some of the incomers had again retreated; a few remained till the Castlecliffian, but the descendants of all are in Recent times limited to areas directly under the influence of the Subantarctic Zone of surface waters. The implication is that subantarctic waters, which, in a pure state, now affect only Southern Otago, Stewart Island, the Chatham Islands, and islands to the south (Forsterian, Moriorian, and Rossian marine faunal provinces) advanced and then retreated, probably as a localised tongue or current, during the Pliocene.

(a) *Chlamys delicatula* (Hutton).

The most characteristic mollusc of this cold water faunule is the lineage group of *Chlamys delicatula*.(Hutton). The earliest record of this group is in the Opoitian of the Chatham Islands, as the somewhat specialised *C. seymouri* Marwick, which is probably not the ancestor of later forms. There is no record of the lineage from Opoitian beds on the main islands of New Zealand. *Chlamys delicatula,* or a closely related ancestral form, first appears in New Zealand in certain beds of North Canterbury (N.Z.G.S. Locs. 2555, Lowry Peaks. SD., 3297, Stonyhurst S.D.) where the associated fauna includes *Manaia manaiaensis* (Marw.), *Phialopecten triphooki* (Hutton), *Polinices waipipiensis* (Marw.), and *Austrofusus pagoda* Finlay, all of which indicate Waitotaran age. There is, however, no trace of the species in the well-collected Waitotaran beds of Westland, Marlborough (King, 1934), South Taranaki (Powell, 1931; Laws, 1940) nor in the Waitotaran of the Eastern North Island from Palliser Bay to Hawke's Bay. In the Lower Nukumaruan, a zone recently recognised in southern Hawke's Bay (Lillie and Fleming, 1941) *Chlamys delicatula* is sufficiently widespread and strictly limited to be used as a key species to a zone intermediate between the Waitotaran and Petane (Upper Nukumaruan) beds throughout the area from Palliser Bay (King, 1933) to just north of Dannevirke (including Castlepoint, Powell, 1938). In the Amuri-Kaikoura area *C. delicatula* is abundant in beds which appear from associated forms to be Lower Nukumaruan. The species occurs in Lower Nukumaruan beds which cross the axial divide at Manawatu Gorge (G.S. Loc. 2779, Gorge S.D.; see also Wild and King, 1932, Pohangina) and in north-west Wellington between the

Manawatu and Rangitikei Rivers (G.S. Loc. 3096, Tiriraukawa S.D., collected by officers of Superior Oil Co.). In the areas where the species was so abundant in the Lower Nukumaruan, it had disappeared completely in the succeeding Upper Nukumaruan ("Petane") zone (Lillie and Fleming, 1941).

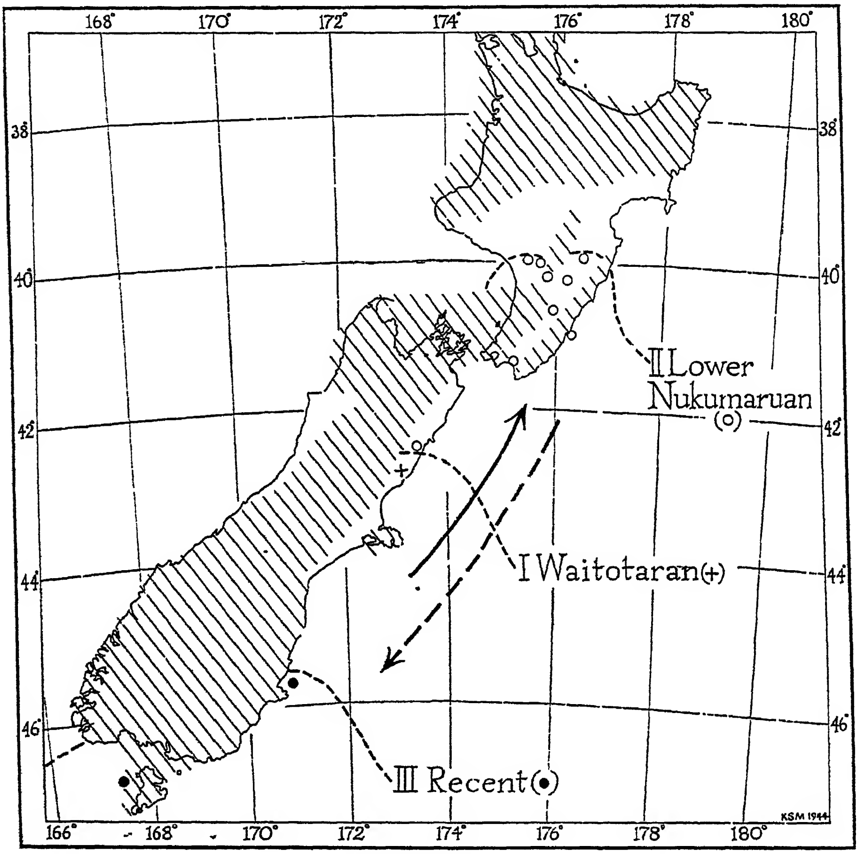

FIGURE 1.

The distribution of the *Chlamys delicatula-campbellica* lineage in Pliocene and Recent times, showing its northward expansion in the early Pliocene, and its present restriction to southernmost New Zealand. Probable land in Pliocene shaded.

In spite of its wide distribution as an abundant fossil in the middle region of New Zealand in the Lower Nukumaruan, *Chlamys delicatula* has never been collected from the Wanganui-South Taranaki Nukumaruan (e.g., Laws, 1940) nor from the richly fossiliferous "Petane" beds of Hawke's Bay north of about 40° S. Lat. so that the species reached its limit there in the Lower Nukumaruan.

There is no record of the southward retreat of the northern limit of the species in Upper Nukumaruan and Castlecliffian beds in the South Island, but the distribution of the Recent *C. campbellica* Odhner, which is with little doubt "the direct Recent descendant

of the Pliocene *delicatula* " (Powell, 1939), shows that such a retreat took place. *C. campbellica* was described from Campbell Island, and has been identified from Auckland Island, off Macquarie Island, Stewart Island, and off Otago Heads (Powell, *op. cit.).* These localities are all within the Subantarctic Zone of surface water as described by Deacon (1936); to the north is an ill-defined belt of mixed water which is not truly of subantarctic nature and which limits the northward range of many subantarctic organisms (Fleming, 1939, 1941). *C. campbellica* is apparently one of such zonally limited ("stenozonal") organisms, and the northern extension of the range of its Pliocene ancestor suggests a northward advance of subantarctic water in the Pliocene.

Odhner (1924, p. 62) compared *campbellica* with *C. patagonica* King, from the coasts of Patagonia, Tierra del Fuego, and the Falkland Islands—all within the Subantarctic Zone of surface waters. In Patagonia, *patagonica* appears to have Pliocene and Miocene ancestors and has been associated with them by Ihering (1907, p. 250) within his subgenus *Zygochlamys.* Ortmann's figures (1902, Pl. XXIII, fig. 2 a–e) of the subgenotype *geminata* Sow. show a shell superficially not unlike the New Zealand *delicatula* assemblage, and the group may prove to have had a common ancestry and to have developed in the Subantarctic on both sides of the Pacific.

(b) *Tawera subsulcata* (Suter).

This species has long been regarded as a reliable key species to the Nukumaruan (Finlay and Marwick, 1940, p. 127) and since the more persistant *T. spissa* lineage can be traced from Recent to Miocene times the sudden appearance and extinction of *subsulcata* suggests that it was an immigrant form. *T. bollonsi* Powell, from the Auckland Islands, has been compared with *subsulcata* by its author (1932, p. 69). The resemblance may be due to environmental effects or to genetic relationship, but in any case the restriction of the *subsulcata* type of sculpture to the Nukumaruan in New Zealand and the occurrence of a similar form in the Subantarctic Recent fauna backs up other evidence of the nature of New Zealand mid-Pliocene seas.

(c) *Stiracolpus* aff. *symmetricus* (Hutton).

The restriction of the Recent *S. symmetricus* (Hutton) to southern New Zealand suggests that it may be stenozonal. The occurrence of close relatives in abundance in the Waitotaran of North Canterbury (but not in the Waitotaran of Westland and of the North Island where occurs a different line, *huttoni* Cossmann, *haweraensis* Powell) and the wider distribution of *symmetricus* in the Nukumaruan and Castlecliffian of the middle North Island are hints that its ancestors may have been members of the cold water *C. delicatula* fauna which came north in the Pliocene. The case of *S. symmetricus,* however, is complicated by the occurrence of relatives in earlier stages (such as *kaawaensis* Laws).

(d) Genus *Zephos* Fin.

The only Recent species of the genus *(otagoensis,* Fin.) is so far only known from the Forsterian Province, so that the surprising abundance of the genus in the Waitotaran of North Canterbury

(*purchasi* Suter, *cingulata* Hutton) and in the Lower Nukumaruan of Palliser Bay (*onokeana* King) may be related to cooler seas.

(e) *Eucominia* aff. *nassoides* (Reeve).

The " superspecies " of *E. nassoides* (Rve.) is, like the preceding species, confined in the Recent fauna to areas directly affected by water of the Subantarctic Zone, races of the group being known from the Chatham Islands, Stewart Island, Foveaux Strait, Otago Heads, and the Subantarctic Islands. The group thus appears to be stenozonal and subantarctic, and its occurrence, as a close ally of *nassoides,* in places associated with *Chlamys delicatula,* in the Lower Nukumaruan of North Canterbury (G.S. Loc. 1590, 1592, Hawkeswood S.D., etc.) and of Dannevirke (2500, Tahoraite S.D.) substantiates the conclusions drawn in the previous section. Other species of *Eucominia* which are not within the lineage group of *E. nassoides* (*elegantula* Fin., *verrucosa* Fin., *excoriata* Fin.) were more widespread in the Nukumaruan and Castlecliffian and were possibly more tolerant, though the absence of the genus in North Island Recent seas suggests that the whole genus was to a certain extent stenozonal at least during the Pliocene*.

(f) *Ellicea* aff. *orbita* (Hutton).

Crass-shelled species of *Ellicea* such as *orbita* (Hutton) and *coronata* (Powell) appear to represent a somewhat different stock from the *henchmani-conformata-perobtusa* lineage (Upper Miocene to Waitotaran). A direct ancestor of *orbita* first appears in Opoitian beds in Southland (G.S. Loc. 2954, Rowallan S.D.); the species is present in Waitotaran beds in North Canterbury (e.g. 1589, Hawkswood S.D., 3297, Stonyhurst S.D.) and in Lower Nukumaruan beds in both Canterbury and South Wellington (King, 1933). The genus did not survive the Lower Nukumaruan, so that there is no proof that it had cold-water affinities, but its northward expansion with *Chlamys delicatula* and other forms is suggestive of pre-Pliocene origin somewhere in the south of the New Zealand region.

Pliocene faunas contain a number of other puzzling Buccinulid forms which have no Miocene " roots " and which probably entered from the south with the cold water fauna here described.

(g) *Miscellaneous:*

New Zealand Recent species of *Gaimardia* Gould are entirely restricted to areas within the influence of subantarctic surface waters; a Nukumaruan species has been described by Laws (1940) from the Wanganui coast.

The genera *Lironoba* Fin., *Zeadmete* Fin., and *Monodilepas* Fin. have their major development in the Subantarctic Zone of surface water in the New Zealand area, but Nukumaruan or Castlecliffian representatives have been recorded for all. The three genera are, however, present in the subtropical waters of the Aupourian marine province where they are members of an anomalous subantarctic element mentioned by Powell (1940, p. 205). Such an anomaly may weaken but does not invalidate the significance of such genera in the North Island Pliocene.

* The Miocene species (*marshalli* Laws, *media* Hutton, *nana* Fin., *intermedia* Suter) are not typical and probably not ancestral.

Summary:

The occurrences listed above suggest that seas belonging to the Subantarctic Zone of surface water began to affect the North Canterbury area (but not Westland) in the Waitotaran; that such waters reached into Southern Hawke's Bay, and, through the Manawatu Strait, to the Rangitikei in the Lower Nukumaruan; and that the Upper Nukumaruan saw a withdrawal of Subantarctic waters from such latitudes towards their present position where, in a pure state, they affect only southernmost New Zealand.

The conclusion that sea water isotherms reached their northernmost position in the New Zealand mid-Pliocene can only be reconciled with a glaciation in the Pleistocene on the assumption that some purely local cause operated to warm, or to prevent the further cooling of, New Zealand seas in post Nukumaruan times Evidence for such an assumption is to be found from examination of Castlecliffian (Uppermost Pliocene) molluscan faunas.

CASTLECLIFFIAN SEAS: THE NOTONECTIAN IMMIGRATION.

The sudden appearance in the Castlecliffian beds of mollusca of East Australian origin which have no direct ancestors in earlier New Zealand beds has been commented on by Finlay (1925, 1926, etc.), and the list of species in the Recent fauna of late derivation from East Australian sources is now of imposing length. The characteristics of the Notonectian element in the New Zealand molluscan fauna are:—

(a) Closer relationship with Peronian representative forms than with possible New Zealand Miocene ancestors.

(b) Sudden appearance in the Castlecliffian or in the Recent fauna.*

(c) Predominance of groups tending to be limited elsewhere to subtropical waters.

(d) In the Recent fauna, the Notonectian element is predominant in the North Auckland (Aupourian) faunal province and progressively less important further south.

(e) Of gasteropods, relatively large numbers have polygyrate protoconchs, sometimes of "*Sinusigera*" or "*Agadina*" form, which (Iredale, 1911) are associated with free-swimming, long-lived embryos.

It has generally been assumed (Finlay, 1925, 1926, etc.; Powell, 1927, 1933, 1940, etc.) that such molluscs owe their presence in New Zealand to the Notonectian Current, which, sweeping past New Caledonia as a southward branch of the South Equatorial Current, passes down the east coast of Australia and Bass Strait, swings eastward across the South Taman Sea and northward to affect chiefly northern New Zealand shores (Deacon, 1936). The fauna

* Such a definition excludes the genera *Glycymerula* F. and M., *Gomphina* Moerch and *Zethalia* Finlay, which arrived in New Zealand in the early Pliocene. They do not seem to be of Australian derivation and may represent a previously unrecognised immigration from the north. All have North-West Pacific affinities which in the first two genera have been noted by Marwick, 1927, and Finlay and Marwick, 1937.

which the current is believed to have transported to New Zealand began to arrive in the Castlecliffian, and Finlay (1931, p. 3) concluded that "such ocean current influence . . . does not seem to have antedated the Castlecliffian."

The Notonectian is a warm, subtropical current, and the fauna it brought is composed of chiefly subtropical stenozonal types. If the Notonectian commenced to operate in the uppermost Pliocene, it provides the clue, not only to the arrival of the warm-water Notonectian molluscs, but to the retreat southwards of the subantarctic fauna described in the preceding section. Put in another way, advance of cold waters northwards in the Pliocene would have culminated in the Pleistocene (when air temperatures reached their minimum) had not the Notonectian current begun to operate as a purely local South Tasman influence, and to blanket New Zealand seas from further cooling after the mid Pliocene. (There is no reason why air temperatures should have shown precisely parallel changes with sea temperatures—many discrepancies occur in Recent geography—and the present hypothesis is put forward to reconcile the anomalies which have previously hindered interpretation of Pliocene-Pleistocene faunal development.

Castlecliffian seas are believed to have been warmer than those of the Nukumaruan, and particularly Lower Nukumaruan, for the following reasons:—

(1) Several of the cold-water forms of the Nukumaruan (*Chlamys delicatula, Tawera subsulcata, Eucominia nassoides, Zephos, Ellicea*) had retreated or become extinct by the Castlecliffian.

(2) The incoming Notonectian element contains groups [*Cymatiids, Cassids, Eunaticina, Heliacus, Agnewia* (at Cape Runaway, Powell, 1934)], which elsewhere show, though to a varying extent, a preference for subtropical conditions.

(3) In the Cassididae, it has been noted (Fleming, 1943, p. 98) that the Waitotaran saw the extinction of the subgenus *Mauicassis* which had developed in New Zealand in Mio-Pliocene times, and that the family is completely absent from the Nukumaruan. Its reappearance (as *Xenophalium* s. str.) in the Castlecliffian points to an alleviation of the cold conditions which had presumably caused its extinction.

Allan (1937) has suggested that the brachiopod assemblage of the Castlecliffian is that living at present in Foveaux Strait, though his suggestion as to the nature of the faunal migration implied requires modification in the light of the contents of this paper. His suggestion that Castlecliffian seas were somewhat cooler than those of the same latitudes at present is further confirmed by the persistence in the Castlecliffian of North Wellington of *Stiracolpus* aff. *symmetricus* (Hutton); *Eucominia elegantula* Fin., and species of *Monodilepas* and *Zeadmete* (with the reservation made earlier concerning the latter two genera).

The evidence indicates that Castlecliffian seas were decidedly warmer than those of at least Lower Nukumaruan times and that they were possibly slightly cooler than those of Recent seas in the area. It is suggested that the Notonectian current commenced to

affect New Zealand sometime between the Lower Nukumaruan and the Castlecliffian and that the current continued to operate during the Pleistocene and Recent Periods and thus effectively blanketed New Zealand seas during the Glacial Period when there was doubtless a marked northward advance of cold water isotherms in other parts of the world. Changes of the type suggested may well be connected with Pliocene orogenic movements in the South West Pacific which might have raised or lowered barriers across the paths of oceanic currents, deflecting them to new courses or allowing them passage where previously diverted.

Molluscan Changes During the Pleistocene.

Few of the post-Pliocene changes in benthic marine mollusca can be attributed to the Pleistocene glacial cooling: the extinction of *Leucotina* A.Ad. (s. str.), *Eunatacina, Pterochelus, Barytellina* might be attributed to such a cause, were it not for the persistence of a far greater number of apparently warm water types and the relative unimportance of other faunal changes.

An extinction which can without doubt be attributed to Pleistocene cooling is that of *Anadara trapezia* (L.). Oliver (1923) has recorded dead shells of the species from northern New Zealand and Powell (1932) has given further details and noted that its extinction in New Zealand is paralleled by its occurrence in Tasmania and southern Australia as a Pleistocene fossil in raised beaches. The species now lives in subtropical mudflats along the East Coast of Australia, where it lies half-buried so that, as suggested by Hedley (1915), exposure to frost when the tide is out might prove fatal to its existence (see Powell, 1932, p. 71, for full discussion).

The occurrences in New Zealand are (1) as worn shells on beaches and dunes formed partly by the erosion of extensive deposits of ancient sands of the Kaihu Series which Ferrar (1934, p. 44) places in the Older Pleistocene (Karekare, Muriwai, Waipu, Spirits Bay). (2) As pairs of valves *in situ* in ancient muds of the Hokianga Harbour (Powell, *op. cit.).* (3) From a baked mud beneath a basalt flow from the Pleistocene-Recent cone of Rangitoto, Auckland (specimen collected by Miss L. B. Moore). Turner and Bartrum (1928, p. 984) suggest that similar estuarine silts and volcanic eruptions in the Takapuna area, not far from Rangitoto, preceded the major submergence of Auckland Province and are Pleistocene. If the extinction of *Anadara trapezia* (L.) be attributed to the glacial cooling, its presence in the above beds confirms their age as Older Pleistocene.

The Development oe the Marine Faunal Provinces.

The regional differences between the Recent mollusca of, say, North Auckland and Stewart Island are not paralleled by similar differences between the Miocene faunules of, for example, Pakaurangi Point and Clifden, Southland. Some time since the Miocene the faunal provinces have developed.

The faunal provinces recognised in the New Zealand Region by Finlay (1925, 1926) and Powell (1937, 1940, etc.) owe their distinctness from each other to a combination of several factors:—

(a) To the development of representative forms in partial or complete isolation [e.g., the sub-species of *Haliotis virginea,* Gmelin, of *Struthiolaria papulosa* (Martyn), of *Thoristella chathamensis* (Hutton), and the sibling species *Fractarmilla corrosa* (A.Ad.) and *subrostrata* (Gray), etc.]. (b) To the ecological (chiefly hydrological) differences between various areas, which control the presence and absence of forms with a limited range of tolerance. (c) To the direction and nature of dispersal mechanisms (currents, coastlines) enabling interchange between populations. (d) To the complex of historical accidents in the past history of an area which may have upset the exact correlation between present conditions and faunas. Five provinces are at present recognised (Powell, 1937, etc.)

(1) *The Aupourian Province* (northern part of North Island). The area may have experienced some isolation suggested by some of its endemic representative forms (*Alcithoe depressa* Suter, *Venericardia reinga* Powell, etc.) but owes its characteristics chiefly to its

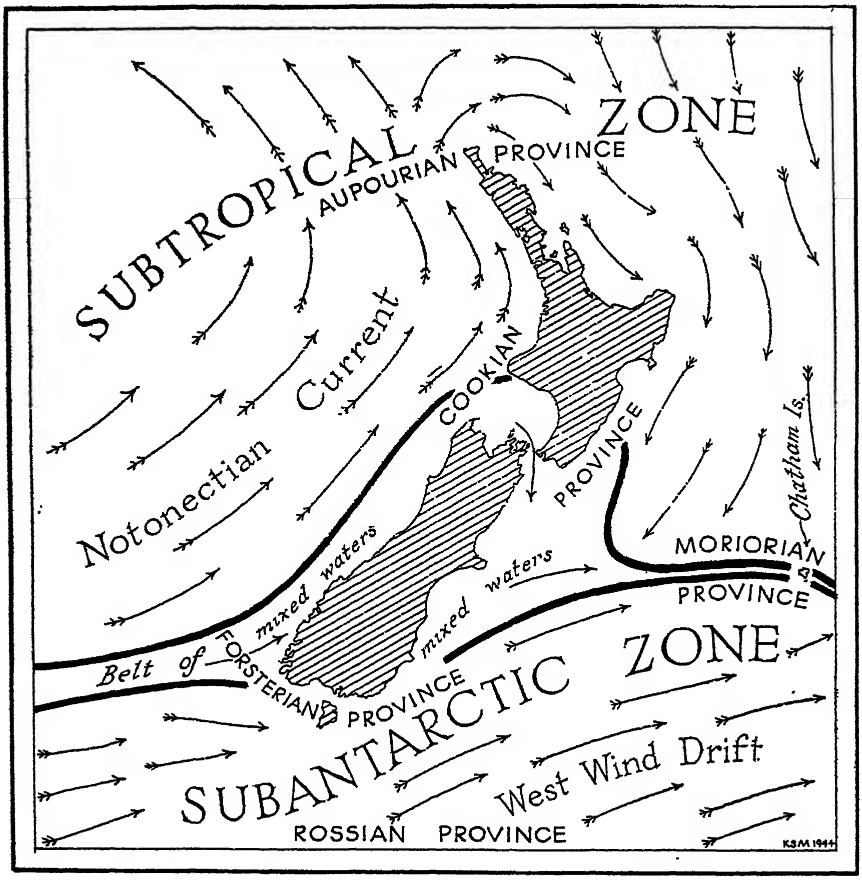

FIGURE 2.

Marine Faunal Provinces in the New Zealand region, and their relation to the zones of surface water. Hydrology based on Deacon (1936) with modifications.

position well within the Subtropical Zone of surface water under the influence of ex-tropical warm currents including the Notonectian. To these factors it owes the presence of many Peronian and some Kermadecian elements (Powell, 1940). The currents have, in at least some cases, enabled such forms to colonize, and the subtropical conditions have enabled them to stay. In view of that, the presence of a distinct southern element in the fauna is an anomaly suggestive of a subantarctic influence sometime in the past.

(2) *The Cookian Province* (middle regions of New Zealand). Largely in the belt of mixed waters and containing chiefly euryzonal forms of a fairly wide tolerance. Few limited subtropical and subantarctic forms occur.

(3) *The Forsterian Province.* A good deal of isolation in the past is suggested by the number of endemic representative forms, but the chief factor is the predominant influence of subantarctic waters enabling the colonization and persistence of subantarctic limited (stenozonal) forms *(Kerguelinia, Gaimardia,* etc., Powell, 1939).

(4) *The Moriorian Province.* The Chatham Islands attest their lengthy isolation by the number of endemic representative forms in their molluscan fauna, but their position on the Subtropical Convergence under direct influence both of warm currents from the N. and of the Subantarctic West Wind drift has resulted in the presence together of forms of diverse origins and affinities which have been remarked on by both reviewers of the fauna (Finlay, 1928; Powell, 1933).

(5) *The Rossian Province* is entirely within the Subantarctic Zone of surface water and has an impoverished fauna containing only the most tolerant (euryzonal) of New Zealand genera, with the addition of stenozonal subantarctic types. Under present conditions communication by currents between the Rossian and other provinces must be limited to a one-way traffic *towards* New Zealand, so that any suggestions of reverse migration imply different conditions in the past.

Since the differences between the provincial faunas cannot have arisen spontaneously in Recent times, the probability that past faunas, no less than living ones, showed regional differences, must be considered. As already stated, there is little evidence for such regional developments in the Miocene, but in the Pliocne there are indications that regional provinces were developing as a response to both the geographic and the hydrological evolution of modern New Zealand. The latter, hydrological, influence seems to have been most important: New Zealand lies athwart the junction (Convergence) of two contrasting zones of surface water (Deacon, 1936), which have divergent faunas elsewhere in the world, so that a northward movement of the Convergence across the New Zealand area in late Tertiary times or its fluctuation back and forth would have profound faunal consequences.

In the Opoitian (Lowest Piocene) differences between the Kaawa Creek (Laws, 1936, etc), the Chatham Island, and other

New Zealand coeval faunas are possibly of such a regional type. In the Waitotaran, the faunas of Taranaki and Westland form a western province with many similarities; in the east, facies differences tend to obscure the issue, but the North Canterbury cold water faunule obviously represents a faunal province under distinct hydrological conditions. The same may be said of the Nukumaruan: the faunas with the cold water element have the same relationship to more northerly faunas lacking it as has the Forsterian fauna to the Cookian. Castlecliffian beds are not sufficiently widespread to show clear provincial differences which doubtless existed: the Cape Runaway fauna lacks *Eucominia* and *Stiracolpus,* and includes *Agnewia, Austrosassia* and other Cymatiids, *Heliacus,* and *Nassarius,* suggesting warmer water conditions than in the Wanganui Castlecliffian.

Summary and Conclusions.

Analysis of Pliocene faunal trends leads to the following, necessarily tentative, conclusions:—

(1) In the Miocene, the New Zealand area lay wholly within the Subtropical Zone of surface waters, and there is no indication of faunal zoning due to hydrological differences.

(2) In the early Pliocene (Opoitian-Waitotaran) subantarctic waters aproached New Zealand; a tongue of such waters had reached North Canterbury on the east coast by the Waitotaran, but did not affect other Waitotaran seas to the west and north.

(3) By the Lower Nukumaruan (Mid Pliocene) subantarctic waters had extended north through North Canterbury, Marlborough, Wellington, and Southern Hawke's Bay to approximately 40° S. latitude.

(4) Continued advance of southern waters was inhibited by the commencement, in the late Pliocene, of the Notonectian current of subtropical water which drove subantarctic waters south from their position in the Nukumaruan and prevented New Zealand seas from reflecting the further cooling which occurred in air temperatures and culminated in the Pleistocene glaciation.

(5) Among the marine mollusca the only case of a Pleistocene extinction due to cooling climate is of an intertidal form vulnerable to low air temperatures.

(6) The marine faunal provinces in New Zealand developed in the Pliocene as a response to the above hydrological changes and now reflect chiefly present conditions, though, to a lesser extent, conditions in the past may have left relict faunal elements.

(7) The conception of New Zealand in the Pleistocene as a land of frigid meteorology set in relatively temperate seas may have important corrolaries in assessing the response of other organisms to the glacial period.

Acknowledgments.

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Some Additions to the Naturalised Flora of New Zealand.

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[*Read before Wellington Branch, July 7, 1944; received by the Editor, July 27, 1944; issued separately, December, 1944.*]

This paper records a number of species not previously reported from New Zealand, and gives noteworthy extensions of distribution of previously recorded species. Some seven species recorded in a previous paper (Healy, 1943) are noted here, as the fact that they were new records for this country was not then mentioned. The writer wishes to acknowledge the assistance of Dr. H. H. Allan, and Messrs. V. D. Zotov (*Gramineae*) and I. W. Davey (*Cyperaceae*) of the Plant Research Bureau in identification of certain critical species. Specimens of the species mentioned in this paper are deposited in the herbarium of the Botany Division, Plant Research Bureau, Wellington.

Cruciferae.

Camelina sativa (Linn.) Crantz. Gold of pleasure. Recorded by Cheeseman (1883, p. 276) for Auckland, this species has been recently noted in linen flax crops in Canterbury.

Lepidium sativum Linn. Garden cress. This species has been found in linen flax crops in both islands, having apparently been introduced via imported flax seed. Onga Onga, Hawke's Bay, J. N. Palmer! Blenheim, A. Smith! Lincoln, near Christchurch.

Cardamine pratensis Linn. Lady's smock. Recorded from Whangarei by Allan (1940, p. 67), the species has now been found at Rata and Silverhope, Mrs D. M. Mason! Foxton, H. H. Allan!

Resedaceae.

Reseda alba Linn. Mignonette. Thomson (1875, p. 372) records the species as *R. suffruticulosa* Linn. from Dunedin, and later (1922, p. 378) from Poverty Bay and Canterbury. It has been noted in arable land, Feilding; waste land and gardens, Mt. Victoria and Lyall Bay, Wellington.

Crassulaceae.

Tillaea decumbens Willd. This plant has been found to occur on ballast in railway yards at Shannon; Levin, Waikanae, Paraparaumu, Pukerua Bay, Takapau Road. The distribution is indicative of the fact that spread is by means of ballast for railroad tracks.

Caryophyllaceae.

Lychnis flos-cuculi Linn. Ragged Robin. Noted in waste land, Shannon, J. Mitchell!

Portulacaceae.

Portulaca oleracea Linn. Purslane. Recorded only from the North Island, this species has been noted in the southern and eastern

parts of the South Island. Occurs as a weed of tobacco and tomato fields and waste places at Nelson, Motueka, Appleby, Richmond, Riwaka; on gravel ballast of railway lines at Picton, Blenheim, Parnassus, Spotswood, Waiau-ua River, Mina and Waipara; appears to be a true ballast plant in Marlborough and North Canterbury. Noted in waste land, Kaiapoi, A. M. Forbes!

POLYGONACEAE.

Polygonum sachalinense F. Schmidt. Sacaline. Allan (1935, pp. 96–97, 1940, p. 282) records this species for the North Island; specimens referrable to this species have now been collected from Motueka and Riwaka, in the latter station it being well established in several patches.

† *Polygonum mite* Schrank (Europe).

Polygonum convolvulus Linn. Cornbind. A variety of this species (var. *subulatum* Lej. et Court) with winged perianth segments has been found at Appleby and Riwaka.

Rumex scutatus Linn. Established in waste land, Tauranga, D. Cairns! Wellington: abundant about the town of Foxton. That our specimens belong to the true *R. scutatus* Linn. is not certain, since they all possess large tubers, a character not mentioned in foreign floras.

PHYTOLACCACEAE.

Phytolacca octandra Linn. Inkweed. Recorded from the North Island by Allan (1940, p. 87), it has been noted as well established about Kaikoura and Oaro, with other scattered occurrences throughout the Marlborough Province.

CHENOPODIACEAE.

Chenopodium pumilio R. Br. This species is common in tobacco fields about Motueka and Riwaka, and is thoroughly established on the Waiau-ua River near Parnassus. It occurs as a ballast plant along the Main South Trunk Railway from Picton to Wharanui.

AMARANTHACEAE.

Amaranthus deflexus Linn. Low amaranth. Allan (1940, p. 91) records this plant for the North Island, and it has now been found at Richmond; there is a specimen without collector's name from Port Nelson in the Plant Research Bureau Herbarium.

Amaranthus lividus Linn. Purple amaranth. Recorded by Kirk (1870, p. 142) for Auckland, but was apparently non-persistent. Has been collected at Ruakura, A. L. Poole! Turakina, K. E. Reynolds!

* *Amaranthus blitoides* Wats. Occurs sparingly on depleted land on lower slopes of Dunstan Mountains, near Lowburn, H. H. Allan!

GERANICEAE.

* *Geranium pusillum* Linn. Small-flowered geranium (Europe). Established on ballast (English origin), Wellington Harbour.

† *Pelargonium radula* Ait. (South Africa).

* *Pelargonium ribifolium* Jacq. (South Africa). Has been collected on waste land near Paekakariki, where it is well established.

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† Species recorded for first time in previous paper (Healy, 1943, pp. 324–332).

* Species recorded for the first time in New Zealand.

OXALIDACEAE.

Oxalis corniculata Linn. A stout form of this species with reddish foliage and stems and large flowers [var. *corniculata* Zucc. forma *tropaeoloides* (Schlachter) R. Knuth] escapes from gardens, and is established in urban districts; Feilding, Shannon, Wellington.

Oxalis rubra A. St. Hil. First recorded by Allan (1940, p. 285), but the distribution is not given. Has been found as an established garden escape; Tauranga, M. Hodgkins! Onehunga, H. Carse! Feilding; Palmerston North, V. D. Zotov! Paekakariki, V. D. Zotov! Wellington City and suburbs, H. H. Allan! Riwaka; Nelson; Christchurch. A white-flowered form has been collected at Wellington, R. Mason! This appears to be that cited as establishing in California (Rose, in Leaflets of Western Botany, vol. i, no. 6, 1933, p. 51), but Knuth (1930, p. 203) makes no mention of such white-flowered forms.

Oxalis variabilis Jacq. Recorded by Cheeseman (1883, p. 279) for Auckland. Other specimens have been collected from that area by H. Carse, and it has recently been found to be established in one locality at Wellington. All the specimens examined belonged to var. *rubra* Jacq. of the species.

* *Oxalis incarnata* Linn. (South-west Africa; South Africa.) A persistent garden escape established on roadsides, in gardens, etc. Has been collected from Feilding; Palmerston North; Tauranga, M. Hodgkins! Shannon; Wellington and suburbs; Blenheim; Nelson.

BALSAMINACEAE.

* *Impatiens roylei* Walp. (Western Himalayas). Noted as a garden escape in both Islands; Erua; roadside, Moutoa Swamp, Shannon; waste land, Lower Hutt; in damaged forest, Ballance, Miss E. G. Thorpe! Paparoa, Westland, L. Cockayne!

HALORRHAGACEAE.

Myriophyllum spicatum Linn. Recorded by Allan (1940, p. 285) from Lake Ellesmere, has now been found in water races at Springfield, Canterbury, H. Talbot!

MALVACEAE.

† *Lavatera cretica* Linn. (Mediterranean region).

Malva moschata Linn. Musk mallow. Recorded by Smith (1904, p. 217) for Ashburton, and by Allan (1940, p. 106) from Piopio, it has now been found in the Orautoha Valley, J. E. Attwood! and at Masterton, N. Lamont!

ROSACEAE.

Duchesnea indica (Andrew) Focke. Indian strawberry. Recorded from the North Island and from Christchurch, South Island, has been found to be well established in damaged forest, Motueka.

Potentilla recta Linn. Tall cinquefoil. Thoroughly naturalized (± 50 acres in extent) near Blenheim, E. Reid!

* *Filipendula hexapetala* Gilib. Dropwort. (Eurasia.) Has escaped from flower beds and established on banks and in lawns, Makino, near Feilding.

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* Species recorded for the first time for New Zealand.

† Species recorded for first time in previous paper (Healy, 1943, pp. 324–332).

LEGUMINOSAE.

Lathyris pratensis Linn. Meadow pea. Smith (1904, p. 218) records the species from Ashburton, and it has now been found near Gore, S. D. Blomfield! Allan (1940, p. 291) mentions the species and gives a description; the description, however, is not that of *L. pratensis* but that of *L. hirsutus* Linn. *L. pratensis* Linn. differs from the latter species in the yellow flowers and glabrous pods.

Trifolium parviflorum Ehrh. Recorded by Allan (1940, p. 291) from Feilding, has now been found to be established in dry pastures and on roadsides, Weld Pass and Dashwood Pass, Marlborough.

* *Parochetus communis* Hamilt. Shamrock pea. (Tropical Asia.) A garden escape established on damp banks; Wellington, I. A. McNeur! Blenheim.

* *Lotus tetragonolobus* Linn. Winged pea. (Mediterranean region.) The species has been found at Hastings; Dunedin; Waimangaroa, R. B. Wells!

Vicia narbonensis Linn. Recorded by Kirk (1899, p. 120) from Great Barrier Island, has been found at Nelson, D. Merry!

URTICACEAE.

* *Urtica gracilis* Ait. (North America). This species has been noted at Raetihi, J. E. Attwood! Tamahere, near Hamilton, G. L. Sharpe!

RHAMNACEAE.

Cryptandra amara Sm. Recorded by Allan (1940, p. 292) from near North Cape, has recently been found to be thoroughly and extensively naturalized in shrubland areas from Te Kao northwards. A. D. Beddie! Mrs D. M. Mason!

CANNABINACEAE.

Humulus lupulus Linn. Hop. Thoroughly established in damaged forest near Feilding; waste land and roadsides, Longburn; Shannon; Lower Hutt; Motueka; Richmond; Riwaka; Nelson; Blenheim; Cheviot; established in vicinity of old homesteads in bush, etc., Pelorus and Kenepuru Sounds, Marlborough.

AMPELIDACEAE.

Vitis vinifera Linn. Grape vine. Well established in damaged bush, Sheard's Point, Urenui; Shannon; Ohau River; several localities in Pelorous Sounds, Marlborough; occurs very sparingly in damaged bush at Kongahu, Buller County, H. H. Allan!

ARALIACEAE.

Hedera helix Linn. Ivy. Established in waste places, Feilding; Palmerston North; Wellington; Picton; Blenheim; Kaikoura; Waikari; Christchurch; Lyttelton; Nelson; Motueka. Covering coastal rock faces Paekakariki; climbing on pine trees in plantations, Kaituna Valley and Havelock, Marlborough.

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* Species recorded for the first time in New Zealand.

UMBELLIFERAE.

Cacaulis daucoides Linn. Hen's foot. This species recorded by Allan (1935, p. 6) should be expunged from the naturalized flora, since the specimens cited for Ashburton belong to an indigenous species, *Daucus glochidiatus* (Labill.) Fischer, Meyer et Lallemand (*D. brachiatus* Sieb.)

* *Sison amomum* Linn. Bastard stone parsley. (Western Europe: Mediterranean region.) Established on roadsides and in hedgerows, Opotiki, N. Potts!

Apium tenuifolium (Moench.) Thellung. Recorded only from the North Island (Allan, 1940, p. 135), this species was noted as not uncommon in pastures and scrub along the Wairau River, Marlborough.

ERICACEAE.

**Erica cinerea* Linn. Bell heather. (Western Europe.) Occurs in the National Park Region, Volcanic Plateau, in company with *Calluna vulgaris* (Linn.) Hall and *Erica tetralix* Linn.

Erica lusitanica Rud. Spanish heath. Recorded as spreading in several localities in both islands by Allan (1940, p. 138), the species is thoroughly established and spreading in the northern South Island —about Picton and in the Queen Charlotte and Kenepuru Sounds; Wairau Valley, near Hillersden; Kaituna Valley (Marlborough); in abandoned orchard land and manuka heath land, Moutere Hills, and Pangatotara, Motueka River (Nelson).

CAPRIFOLIACEAE.

Lonicera japonica Thunb. Honeysuckle. Recorded by Allan (1940, p. 294) from the North Island, this species has been found in several localities in the South Island—Blenheim, Picton, Havelock, Riwaka, Motueka, Appleby, Richmond, Motueka, Nelson, Kaikoura, Amberley, Waiau.

COMPOSITAE.

Eupatorium riparium C. H. Schultz. Mist flower. Established on banks in a cemetery, Wellington, where it withstands frequent cuttings.

Lagenophora gunnii (Hook. f.) Black. Occurs in pastures and waste land near Motueka and Riwaka.

Vittadinia triloba (Gaud.) D.C. Has been noted at Ruby Bay near Mapua; Okaramio, Kaituna Valley; Blind River, Seddon. Specimens answering to var. *lanuginosa* Black have been collected from the Kaiwarra River, North Canterbury.

Anthemis nobilis Linn. Common chamomile. The species was recorded originally by Hooker (1867, p. 760) for Auckland on the authority of Kirk, and it was later recorded by Kirk (1899, p. 319) as " apparently well established " at the Bluff, Southland; this latter record is omitted by Allan (1940). It has recently been found in lawns near Featherston, E. A. Madden! J. Carne Bidwill!

Solidago canadensis Linn. Golden rod. Noted by Allan (1940,

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* Species recorded for the first time in New Zealand.

p. 296) as an escape in the North Island, this species has been found established on roadsides and in waste places at Nelson, Motueka, Riwaka, Tasman, Blenheim.

Bidens tripartita Linn. Beggar's ticks. Recorded from the North Island only (Allan, 1940, p. 151), has now been found to be well established about a lake in a bird sanctuary near Cheviot. There is also an immature specimen without collector's name in the Plant Research Bureau Herbarium from Rotherham. Since the fruits are modified for animal dispersal, it is likely that the species will be noted elsewhere in the Cheviot district due to the wanderings of ducks, etc.

Galinsoga parviflora Cav. Yellow weed. Recorded from several localities in the North Island, this species has been noted as abundant in cultivated land (tobacco and tomato fields, etc.) at Nelson, Appleby, Motueka, Riwaka; also occurs on roadsides and in waste places.

* *Chrysanthemum* sp. Allied to and probably derived from *C. lacustre* Brot. or *C. maximum* Ramond, this garden escape forms dense thickets (to 6 feet high) on roadsides and in waste places in some localities in both islands—Feilding, Aorangi, Palmerston North, Woodville, Porirua, Wellington, Blenheim, Motueka, Nelson, Riwaka.

Centaurea melitensis Linn. Malta thistle. This species is thoroughly established on the bluffs above the Hurunui River, below the Hurunui Hotel; it is also well dispersed in modified tussock grassland, Mt. Benger Station, Mt. Alexander Station, and Hitchen Hills, North Canterbury.

Carduus nutans Linn. Musk thistle. Previously recorded for the South Island (Allan, 1940, p. 167), this plant has been found in several parts of the North Island—Maungaturoto, North Auckland, J. McRae! Rissington, Hawke's Bay, J. N. Palmer! Wangaehu, J. V. Blythe! Wellington, B. C. Aston!

* *Carduus pycnocephalus* Linn. Winged thistle. This name was first used for New Zealand specimens by Kirk (1899, p. 353) and applied to specimens belonging to *C. tenuiflorus* Curt. The true *C. pycnocephalus* has been recently collected from the Matai River, Nelson, V. D. Zotov, and is established in waste places and pastures at Appleby and Richmond, Nelson.

Mycelis muralis (Linn.) Rchb. Ivy-leaved lettuce. Recorded from Jollie's Pass, Hanmer, by Allan (1940, p. 179) and the Stanton River, Waiau, by Healy (1943, p. 330); its distribution has been extended southwards by its discovery in waste places and plantations about Cheviot, and in scrub along the Hurunui River near Ethelton.

Lactuca virosa Linn. Acrid lettuce. Recorded for several North Island localities by Allan (1940, p. 179), the plant has been noted as established about Picton, Spring Creek, Tua Marina, and Blenheim.

Lactuca saligna Linn. Willow lettuce. This species was recorded by Kirk (1899, p. 361) for Petane, Hawke's Bay; it has been recently found at Gisborne, E. M. Ojala! and immature specimens from Nelson appear to belong to the same species.

* Species recorded for the first time in New Zealand.

Onopordon acanthium Linn. Scotch thistle. Recorded by Smith (1904, p. 220) for Ashburton, this species was recently noted on ballast (of English origin), Wellington Harbour.

Crepis setosa Hall f. Hispid hawkweed. Noted as occurring about Auckland and environs (Allan, 1940, p. 180) this species has been found at Gisborne, P. Haugh! and is well established in waste places and on roadsides at Nelson, Riwaka, Richmond, Motueka, and Blenheim.

Hieraceum pilosella Linn. Mouse-eared hawkweed. Previously recorded from the South Island, has now been found in several North Island localities; in pastures, Argyll, Southern Hawke's Bay, D. McDonald! "Frequent to common in open country through the North Ruahine Ranges," V. D. Zotov! Reporoa Bog, Ruahine Ranges, V. D. Zotov! St. Andrews, Timaru, and well established in modified tussock grassland, Kaiwarra River, North Canterbury.

PRIMULACEAE.

Lysimachia nummularia Linn. Moneywort. Recorded from the Lower Buller Valley by Allan (1940, p. 184) has now been found in damp places, Opotiki Flats, W. W. Hubbard!

POLEMONIACEAE.

**Collomia grandiflora* Dougl. (Rocky Mountain region, U.S.A.) Established in orchard, Ripponvale, Cromwell, Williams! Specimens from Cardrona Valley (Kirk) appear to belong to this species.

BORAGINACEAE.

* *Symphytum asperum* Lepechin. Comfrey. (Eurasia.) A garden escape established in several localities; waste land, Mt. Hutt, Methven, R. Inch; Kaiapoi, on roadsides, Rewa (near Hunterville).

Anchusa officinalis Linn. Alkanet. Recently found on ballast (of English origin), Wellington Harbour, and showing a tendency to persist and spread.

SOLANACEAE.

* *Solanum dulcamara* Linn. Bittersweet. (Europe.) Thoroughly established in *Phormium* swamp, Whitanui, A. L. Poole! Moutoa Swamp, Shannon, A. L. Poole! a garden escape at Hastings, V. D. Zotov! Oroua River, near Feilding! established on roadsides and fringes of plantation, Horsley Downs, near Hawarden.

Solanum pseudocapsicum Linn. Jerusalem cherry. Recorded as occurring in damaged forest in North Island, has been noted in similar situations about Motueka and Nelson.

Hyoscyamus niger Linn. Henbane. Collected by Kirk in 1896 from ballast at Wellington, and later recorded by Cheeseman (1925, p. 1077) from near Pakuranga, Auckland. This species has been recently collected on ballast (of English origin), Wellington Harbour.

CONVOLVULACEAE.

Cuscuta campestris Yuncker. Field dodder. This species has recently been recorded by Allan (1944, p. 45), parasitic on sugar beet at Ohau.

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* Species recorded for the first time for New Zealand.

SCROPHULARIACEAE.

Verbascum blattaria Linn. Moth mullein. Occurs in form *erubescens* Brügger at Bucklands Beach, Auckland, Mrs D. M. Mason! Masterton, N. Lamont!

Antirrhinum orontium Linn. Lesser snapdragon. Recorded by Cheeseman (1906, p. 1082) for Auckland and Napier, and noted as with similar distribution by Allan (1940, p. 206), this species has been found in waste land at Picton, Blenheim, Richmond, Appleby, Motueka, Riwaka. It also occurs, sometimes in quantity, in tobacco fields at Motueka and Riwaka.

† *Linaria arvensis* (Linn.) Desf. (Mediterranean region.) In the earlier paper, acknowledgment of specimens collected by Dr. G. H. Cunningham was omitted, due to the fact that the writer was not aware of these specimens; they were collected about Blenheim some months earlier than the writer's. The species has recently been collected in waste places at Ward.

Veronica americana Schwein. American brooklime. Recorded by Allan (1940, p. 303) from Hamilton, it has now been found at Ashburton, R. McGillivray! W. H. Vaughan!

Veronica hederaefolia Linn. Ivy speedwell. Noted by Allan (1940, p. 303) from Owaka, Otago; it has been collected at Feilding, in 1933.

Veronica verna Linn. Originally recorded by Allan (1940, p. 303) for Fairlie, and later noted from North Canterbury by Healy (1943, p. 332), has now been found to be more widely distributed—Medbury Plains; Black Hills region, North Canterbury; depleted tussock grassland, Molesworth Run, Marlborough, H. H. Allan!

Veronica anagallis Linn. Water speedwell. New localities for this species are in swamps at Spotswood; damp places along the Waiau-ua River, near Parnassus; Kaiwarra River; Beckenham Hills Station, Hurunui River; Waitohi River; Pahau River; Riverlands, near Blenheim. Specimens from Lowry Hills (between Cheviot and Culverden) and Maungaturoto, North Auckland, agree with *V. aquatica* Bernh. having pedicels spreading horizontally, and capsules longer than the calyx members. This latter is maintained as a distinct species by Hegi (1928, p. 63) but the minor differences between the two plants would indicate that it should be considered as a variety of *V. anagallis* Linn.

OROBANCHACEAE.

Orobanche minor Sutt. Broom rape. Specimens have been collected from Kaiapoi, Feilding, and Wellington, which belong to var. *concolor* (Duby) G. Beck. This variety is distinguished by its yellowish colour (see G. Beck-Managetta, 1930, p. 214).

LABIATEAE.

* *Satureja calamintha* (Linn.) Scheele. Calamint. (Eurasia.) Established in hill country behind Puketapu, Hawke's Bay, W. H. Hartree!

† *Satureja vulgaris* (Linn.) Fritsch. Wild basil. (Eurasia.) Recorded from Pelorus Sounds by Healy (1943, p. 331) the species

† Species recorded for first time in earlier paper (Healy, 1943, pp. 324–332).

* Species recorded for the first time in New Zealand.

has now been found on roadsides between Ohakune and Horopito, J. E. Attwood! Rua Roa, near Dannevirke, Edwards! (this specimen previously recorded as *S. acinos* (Linn.) Scheele by Allan, 1935, p. 7); Picton.

Satureja acinos (Linn.) Scheele. Basil thyme. Originally recorded by Kirk (1870, p. 141) as *Calamintha acinos* Clairv. The species is omitted from both editions of Cheeseman's Manual, but is cited by Thomson (1922, p. 460). It is recorded by Allan (1935, p. 7), but the specimens cited were incorrectly determined, and are discussed elsewhere. It has been found recently at Seafield, Ashburton, R. Inch! and there is a specimen in the Dominion Museum Herbarium collected by T. Kirk from Castle Howard Basin (c. 2,500 feet).

Melissa officinalis Linn. Wild balm. Recorded originally by Smith (1904, p. 222) for Ashburton, and given by Cheeseman (1906, p. 1083) as a garden escape in a few localities. The species is recorded by Thomson (1922, p. 460), but is omitted from Cheeseman (1925) and Allan (1940). It has been found in several localities—Takaka, T. Kirk (coll. 1885)! North Manakau Road, R. Mason! Haywards, L. B. Moore! near Waitotara, A. H. Kendall! (this specimen recorded as *Satureja acinos* (Linn.) Scheele by Allan, 1935, p. 7); Maitai, Nelson, H. H. Allan! roadsides and waste places, Nelson; Motueka; Riwaka Settlement and Upper Riwaka Valley; Castelly Creek, North Canterbury.

* *Origanum vulgare* Linn. Wild majoram. (Eurasia.) This pot herb has been found in the wild state at Four Peaks, Geraldine, D. Merry! R. Mason! Ben Lomond, L. Cockayne!

Glechoma hederaceum Linn. Ground ivy. Previously recorded from the Wanganui River locality, this species has recently been noted as established near Cheviot, North Canterbury.

IRIDACEAE.

* *Homeria collina* (Thunb.) Vent. Cape tulip (South Africa). This troublesome species has been recently found established (several acres in extent) in pasture, Hamilton Bay, French Pass, H. C. Hope! The species is recorded from South Australia by Black (1922, p. 114) and Clarke (1939, pp. 30–42), from Victoria by Meadly (1943, pp. 133–137), it causing serious stock poisoning in both States. (A note as to the occurrence of the species appears in the annual report, Dept. S. & I. R. N.Z., which is in the press as this paper is being written.)

* *Romulea* sp. Onion grass. (South Africa.) Specimens of *Romulea* probably *R. rosea* (Linn.) Eckl. have been collected from several North Auckland localities, but sufficiently mature plants have not been found to enable certain determination to be made. Established at Oruaiti and Maungonui, R. B. Steele! Whangarei, F. E. T. Suckling! Pukenui, Miss M. Wagener!

Watsonia bulbillifera Matthews. This species occurs on roadsides about Motueka and Richmond.

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* Species recorded for the first time for New Zealand.

JUNCACEAE.

Juncus gerardi Lois. Recorded from Auckland and Dunedin (Allan, 1940, p. 308); has been noted as well established on mudflats, Havelock, Marlborough. Immature specimens from Porirua Harbour appear to belong to this species.

CYPERACEAE.

* *Carex hirta* Linn. Hairy sedge. (Eurasia.) Occurs in patches on grassy strand around mudflats, Havelock, Marlborough.

* *Carex riparia* Curtis. Marsh sedge. (Eurasia.) Established on sandy peat, Springvale, Wanganui, A. R. Dingwall!

Isolepis setacea (Linn.) R. Br. Recorded from Ashburton by Allan (1940, p. 3), has now been found at Dart River, near Lake Wakatipu, V. D. Zotov! Mt. Benger Station, Hurunui River.

Carex divulsa Good. Recorded by Allan (1940, p. 221) for Auckland, has been collected from other North Island stations; Maungaturoto, A. Griffin! Gisborne, C. Camp! thoroughly well established in grassland and damp waste places, Colyton, Waiata, and Cheltenham (near Feilding), and Arapata, Rangitikei River.

GRAMINEAE.

Cynosurus echinatus Linn. Rough dogstail. Previously recorded from the North Island by Allan (1940, p. 226), has now been collected from the South Island; Halswell, near Christchurch, P. Ruddy! Ashburton; Teddington; Picton; Blenheim.

* *Lolium remotum* Schrank. (Europe.) Has been found in linen flax crops at Dunedin, J. M. Woodcock! This species is reported as associated with linen flax crops in Europe and elsewhere (Hegi, 1906, pp. 337–338).

* *Panicum miliaceum* Linn. Broomcorn millet. (India, Egypt.) An adventive in waste places, appearing to originate from canary seed in most instances. Auckland, P. N. Smallfield! Wanganui, A. R. Dingwall! Feilding; Wellington; Greymouth, E. S. Dalgleish! Blenheim; Ashburton, J. K. McPherson!

† *Koeleria phleoides* (Vill.) Pers. (Mediterranean region.)

* *Ehrharta erecta* Lam. (South Africa.) Specimens agreeing with this species have been collected from footpath crevices, Wellington, and from a garden, Seatoun, Wellington, Mrs Sampson!

Bromus carinatus Hook. et Arn. Previously recorded from Lincoln, Canterbury, by Allan (1940, p. 232) and for Marlborough by Healy (1943, p. 328), this species has been found at Springfield and other stations on railway line to Arthur's Pass, V. D. Zotov! at Cashmere Hills, Christchurch; Westport, I. A. McNeur! Richmond and Motueka. It is therefore shown to be distributed over the northern half of the South Island on both east and west coasts. The grass has been collected near Te Puke, Bay of Plenty, K. W. Allison! and at Tauranga, M. Hodgkins!

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* Species recorded for the first time in New Zealand.

† Species recorded for first time in previous paper (Healy, 1943, pp. 324–332).

Hordeum marinum Huds. Previously recorded from the South Island, has now been collected at Raetihi, J. E. Attwood!

* *Poa palustris* Linn. Fowl bluegrass. (Eurasia; North America.) This species occurs at Moutoa Swamp, near Shannon, A. L. Poole! V. D. Zotov!

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* Species recorded for the first time in New Zealand.

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The Geology of Banks Peninsula—a Revision.

By R. Speight.

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PART II.—THE AKAROA VOLCANO.

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1. Introduction.

Although the Akaroa region has received a good deal of attention, chiefly on account of its historical associations and its landscape features, precise references to its structural geology are somewhat infrequent. Haast (1879) spends on it a little more than a page in his account of the geology of Banks Peninsula, and Hutton (1885) gives it very brief reference. The present author has contributed some account of the area (1917) as well as references to its petrology (1923 and 1924), while his last geological paper on the area (1940) gives an account of the basal beds exposed round the middle and upper parts of the harbour. Later references are by Cotton (1941), in his description of "Some Volcanic Land-forms in New Zealand," and in his masterly account of the phenomena of vulcanity (1944) he states that the Lyttelton and Akaroa volcanoes have the form of lava domes.

In view of this absence of extended description the present author submits the following observations which may serve to fill gaps in accounts already given. As the area under consideration is of considerable extent, with steep slopes, and requires detailed observation in many places, some difficult of access, this account is not meant to be complete, but only an addition to what has already been written in connection therewith.

2. General Geological Features. (Plates 30 and 31.)

Except near the upper edge of the crater-ring and near sea-level the slopes facing the harbour are almost completely masked by a covering of soil and slip-material, and therefore sequent observations from sea-level to the highest peak are virtually impossible. In this respect there is a contrast with the Lyttelton area, which is perhaps

explained by a greater readiness of the Akaroa rocks to respond to weathering under the influence of a heavier rainfall. A proportion of loose material in the surface soil adds to the masking effect. Thus, well-exposed faces at intermediate levels are rare, the Pulpit Rock in French Farm Valley and the bastion fronting French Peak affording striking exceptions to the general rule. On the external slopes exposures are more frequent. They occur frequently on the crests of the ridges, on the sides of the valleys near their seaward ends, and on the cliffs of the coastline. These latter cannot be closely examined since access to them is only by boat, and this is generally difficult and often impossible.

As far as can be seen the upper slopes of the caldera and all the slopes of the periphery exhibit the structures normal to a composite volcanic cone—Cotton would call it a dome—with a subordinate number of those accidental features which modify its regularity. There is the usual alternation of lava-flows and ash-beds, but a precise estimate of the relative importance of the solid and fragmentary constituents cannot be arrived at owing to the completeness of the soil cover. Near the edge of the crater-ring massive breccias are at times strikingly developed. Exposures in the cliffs of the periphery indicate that the thickness of solid material is there greater than that of the fragmentary, if allowance is made for that constituent which is due to deposit under an advancing flow. The finer-grained fragmentary beds are usually rudely stratified, are reddish in colour, with a frequent purplish tint, not only near the shore but at all levels. These beds have rarely a wide extent laterally.

(1) Basement Beds.

The basement on which the volcano has been built consists of plutonics—syenite and gabbro, forming the distal end of Onawe Peninsula—and also trachytoid rocks, which form the major portion of the shelf stretching from Tikao Bay to the vicinity of French Farm (Speight, 1940, pp. 60–76).

Although no contacts between these rocks, either plutonics or trachytes, and those of the cone itself are visible, it seems reasonable to consider them the older of the two, and that they formed an integral part of the foundation on which subsequent building took place (*op. cit.* pp. 74–75). There is also a possibility that an episode of basic extrusion antedated that to which the present cone belongs. It has been pointed out that the rocks exposed round the head of the harbour in the vicinity of Duvauchelles Bay show a degree of decay that would hardly be expected had these rocks belonged to the stage during which the cone was actually built. This suggestion has been adopted by Cotton (1941, p. 303). Examples of such decomposed rock can be noted at the back of the Council Yard at Akaroa, on the lower slopes alongside the road leading from Akaroa towards Stony Bay, and along the shore between Barrys Bay and French Farm. Further, the irregularity in the direction of inclination of the flows round the foreshore of the harbour from Duvauchelles to Takamatua is not in agreement with the hypothesis of an outward quaquaversal dip from a volcanic centre located near Onawe, the position of such a centre being determined by a consideration

of the direction of dip of the beds forming the upper part of the cone. All due allowance must be made for the occurrence of reasonable irregularity due to the chance form of the surface on to which the lavas were outpoured. If the irregularity in direction is due to sagging or incipient fold movements, then it must be urged that the lava flows of the cone show no sign of similar variation in direction of inclination. If this phenomenon is attributed to structural causes then it strengthens the case for the existence of a previous episode of basic extrusion.

In this connection special mention should be made of Otipua Hill, the semi-detached elevation lying between Takamatua and the bay on which the town of Akaroa is situated. The depression east of the hill over which the road passes, and the fact that some of the flows on the western front of the hill do really dip to the east, suggest that it has been constructed of material discharged from a centre beneath the floor of the harbour in close proximity, and that it forms the lower part of the sequence exposed in the neighbourhood of the road leading up the spur to the east in the direction of Long Bay Saddle. There is some doubt, however, concerning this apparently obvious interpretation.

It is unfortunate that the summit and lower slopes of Otipua Hill are in general completely masked with soil, and that rock exposures are visible only in places on the western facing and along the shore; it is the latter which furnish most direct evidence. On the shoreline of the hill nearest to the town the beds consist of interstratified flows, agglomerate, and ash-beds with a general dip to the south-east. This is specially true of the fragmentaries, though all beds have an occasional easterly dip. They are penetrated by trachyte dykes. Over them lies a massive basalt with definite dip to the south-east and forming a considerable stretch of the shoreline with flanking shelves following along the hillside at higher levels. This basalt overlies a different basalt and also fragmentaries, which at their western exposure contain a small amount of trachytic material, some of the pebbles having been rounded in water; they also dip to the south-east. On the next point to the west a massive trachyte occurs and continues on the shore-platform for a chain and a-half. The contacts with the basalt at higher level are obscured so that one cannot give a definite opinion as to whether the trachyte is intrusive or not, but the large extent of the exposure as compared with that of the general run of the dykes suggests that it is not intrusive, so that it may be an outlying member of the trachytes just across the harbour between Tikao and Broughs Bays (Speight, 1940, pp. 68–71). Towards the western point of the bay basalt flows and fragmentaries are interstratified, the amount of the trachyte in the latter increasing and the basic component decreasing as the point is approached; it is probable that a little decomposed rhyolite is also present. The interstratification of the trachyte fragmentaries with basalt flows and the inclusion of a proportion of basic material in them—a proportion which is small in the lower levels but increases upward—suggests that the first basic eruptions broke through a trachyte cover, deposited fragments round the vent, and then as the volcano grew the proportion of trachyte declined and finally the deposited material became entirely basic.

On the western slope of the hill, basalt beds are seen dipping to the east, while along the shore beneath them the dip is variable, and the rocks are much decomposed and intersected by trachyte dykes, some of the latter so wide that they may not be intrusive at all. Fragmentaries, trachytic at the base and with an increasing basic component at higher levels, also occur.

Considerable attention has been paid to this locality, since a correct interpretation of its features is most important if a true idea of the early history of the Akaroa volcano is to be obtained. While it must be admitted that the easterly dip of the beds on the western facing must be seriously considered, the prevailing south-easterly dip of the flows and fragmentaries throughout almost the whole length of the southern shore of the hill affords material for serious consideration of the hypothesis that a volcanic episode occurred antecedent to, and perhaps independent of, that responsible for the building up of what is usually regarded as the present Akaroa cone.

Some reference should also be made to the beds exposed near sea-level on the south side of the bay on which the town of Akaroa lies. The first exposures of basalt that one encounters in this direction appear to have an inclination towards the middle of the bay, a direction which is contrary to what they should have if they were outpourings from a centre located somewhere near Onawe. Further along the shore these basic beds have an uncertain inclination; but when Green Point is reached, a solid basalt lying on a scoriaceous bed shows a definite inclination towards the mouth of the harbour, a direction in agreement with what one would expect were this bed a member of the Akaroa cone series. It seems reasonable to consider the partially submerged reef off Green Point to be a continuation of this basalt.

When speaking of the dip of the beds towards the middle of the bay off Akaroa town as a proof that they did not come from a centre located near Onawe, one must not forget that the inclination of the flows and inter-stratified scoriaceous beds in the direction of this centre may be due to their having been poured out over an irregular surface or that some amount of sagging has taken place after the decline of volcanic activity; but the whole circumstances of the beds south of the town, taken in conjunction with those of the beds exposed on the shore of Otipua Hill, do strongly suggest that they belong to a distinct volcanic episode antedating that responsible for the formation of the cone itself.

The possibility of the presence of basic volcanics belonging to an earlier period is to some extent supported by the fact that, near the gabbro on Onawe, basic volcanics show signs of metamorphism (Speight, 1940, pp. 62–63), that is, these rocks were in position before the gabbro was intruded, and it is also possible that they antedated the intrusion of the syenite.

Otipua Hill and its neighbouring slopes seem to have some physiographic relation with the shelf, composed largely of trachyte flows, on the opposite side of the harbour. Also the break in the profile of the spurs reaching down into the upper harbour, where the decomposed rocks are specially developed, gives some support to

the hypothesis that all these rocks formed part of a basement on which the cone was subsequently constructed, and that this physiographic break marks the approximate position of the pre-existing surface. I am unfortunately unable at the present time to indicate any factor in the analyses or mineralogical composition of the rocks of these two series that may enable them to be differentiated, nor can I indicate the precise upward limits of the presumably older series owing to the obscurity arising from the mantle of soil, beyond the presence of a presumed physiographic break mentioned earlier.

It might be stated here that there are reports of the presence of coal near Lushington Bay, on the western margin of Otipua Hill, but I have seen no evidence of its presence. Haast mentions that fragments of wood turned into anthracite, are to be found in some of the tuffs, and this may account for the report. However, the presence of waterworn pebbles in the fragmentaries on the shore near the south point of Otipua Hill cannot quite be neglected in this connection.

(2) Upper Slopes Facing the Harbour. (Plate 30.)

The upper slopes facing the harbour are formed by the truncation of outward dipping flows, and are frequently bold and precipitous. Notable among these on the western side are Mount Bossu (2386 feet), Saddle Hill (2758 feet), French Peak (2685 feet), Rocky Peak (2297 feet), and on the eastern side Duvauchelles Peak (2406 feet), Okains Peak (1880 feet), Lavericks Peak (2478 feet), and Purple Peak (2643 feet), while extending from the last-named towards the entrance to the harbour are the most striking faces occurring round the crater-ring. Their upper surfaces rise to 2668 feet in Flag Peak, and to 2643 feet in Mount Berard, and fronting them are the precipitous slopes known as Brazenose. From this locality thick flows form the crest and upper slopes of the ridge extending towards the entrance, and are probably continuous—or at all events they belong to the same horizon—with the massive flow, some 250 feet thick, which forms the major portion of the beds exposed in the face of Dam Rogers cliff.

The sharp-pointed masses which dominate that part of the crater-ring between Duvauchelles Peak and Lavericks Peak at the head of Okains Valley, the most westerly one known as Okains Peak, appear at first sight to be dykes, but a closer examination shows this to be unfounded. The top of Okains Peak consists of a mass of basalt, the lower part fine-grained, laminated, and evidently chilled, resting on fragmentary beds under which lie interstratified basalt and fragmentaries. The upper basalt, forming the actual summit, is irregularly columnar, the columns being of large diameter. There is no evidence of intrusion except a small dyke, which does not penetrate the capping. While making an examination, one had always in mind the possibility that it might be a mass which had mushroomed out over the adjoining surface from even a small dyke, but this possibility was considered unlikely.

A similar mass forms a slightly higher peak about half a mile to the south, and they both seem to be remnants of a widely extended flow, which may have formed part of the massive capping near the

summit of Lavericks Peak, a higher elevation about half a mile to the east of Okains Peak.

The peaks round the harbour are almost invariably the terminations of the radiating ridges dividing the external valleys, while between the high points the general level of the edge of the crater-ring takes on beautiful catenary forms, which mark the heads of the external valleys. The internal valleys seem to have developed independently, and their heads rarely coalesce with those of the external slope. These circumstances seem to indicate a considerable erosion of the upper ends of the ridges and that they once extended a considerable distance over the fringe of the area occupied by the harbour.

3. ORIGINAL EXTENT, FORM, AND HEIGHT OF THE CONE.

The boundary of the beds forming the Akaroa cone, as it stands at present, follows round the seaward margin of the peninsula from the western shore of Pigeon Bay on the north to the vicinity of Kaituna on the south, the area covered forming a rough circle 20 miles in diameter. A marginal fringe of uncertain width lies submerged beneath the sea on the eastern periphery and on the south is covered by the alluvial deposits marginal to Lake Ellesmere and by the marine gravels of the Ellesmere Spit. The western boundary presents serious uncertainties. As mentioned in my former account there is no reason to consider either Pigeon Bay or Little River valleys as centres of activity. Also I consider Mount Sinclair to belong to the Akaroa cone for reasons already given (Speight, 1917, p. 383). But the question of Mount Herbert appears uncertain still. The lavas of which its summit and a section of the northern flank are formed were credited by both Haast (1879, p. 346) and Hutton (1885, p. 216) to a centre located in the upper part of Kaituna Valley or even to subsidiary craters on the summit of the mountain and its westerly extension. In my first account (1917, pp. 382–3) I accepted these conclusions, but in a subsequent article (1933, pp. 41–51) the matter was fully discussed and the conclusion tentatively reached that the Mount Herbert lavas came from the direction of Akaroa; the flows on the eastern bastion of Mount Herbert are certainly inclined upward in that direction.

However, the great thickness of fragmentaries, greater than in any other locality on the peninsula, seems to suggest for them a locus of origin in the immediate vicinity. If that is the case, the upper part of Kaituna Valley is probably the spot from which they came, and the valley itself, south of the basin in its upper reaches, has been eroded on the southern flank of a cone constructed in this area, although the valley can quite well be attributed to development along the junction of beds of undoubted Lyttelton and Akaroa origin.

The presence of the thick beds of fragmentary material is certainly not conclusive, for deposits of considerable thickness are exposed in various other localities clearly associated with Lyttelton, and the Kaituna deposit may have come from the same source.

The original form of the cone can be arrived at only by considering the evidence furnished by the existing remnant. There is no doubt that it is constructed of lava flows with a slightly larger volume of interstratified material. The relative importance of these

constituents cannot be precisely determined owing to the small number of clear-cut exposures at intermediate levels and the difficulties of approach to the marginal wave-cut cliffs, and estimates based on observations of the latter are largely impressional. However, on the sea-cliffs the amounts seem in general to be sub-equal, but on the shore-platforms inside the harbour and on the road-cutting near the edge of the crater-ring fragmentaries exceed the lava-flows in thickness by a considerable amount.

The flows near the present summit have an inclination varying between 3° and 15°, but the higher values are rare and the beds are frequently almost flat. At intermediate situations the inclination is generally lower. For example, on the eastern side of Little River Valley (Plate 31) it is 5°, and it is the same at the Devils Gap—to be referred to later—while at the margin of the cone it is still less, and in places the flows are almost horizontal. This low inclination can be clearly seen in the cliffs near Dam Rogers (Plate 31) and at the Akaroa Heads, on the sides of the Little River Valley near Lake Forsyth, and on the periphery between that lake and Kaituna. These inclinations have the general character of those of a lava cone, but it is extremely probable, as Cotton suggests (1944, p. 91) that the roof over the caldera had the form of a flat dome, and in its completed form it resembled in shape the shield volcanoes of Iceland and specially those of Hawaii. The general uniform height of the dominant elevations right round the crater-ring gives support to this suggestion, since such uniformity might be expected to arise as a result of the erosion of a flat dome rather than of a cone. In the latter case irregularities would certainly occur had a long period of erosion followed on the cessation of volcanic construction.

There is some difficulty in arriving at a tolerably accurate estimate of the former height of the volcano owing to the uncertainty of the angle of inclination of the flows that formed the actual summit. The general angle of those on the middle slopes, such as those shown on the flanks of the ridge east of Lake Forsyth and the Devils Gap, is taken to be about 5°, and if this value persisted as far as a centre located near Onawe, a distance of about seven miles, it would mean that the summit formerly reached a height of approximately 5,000 feet.

If the steeper angles occurring near the edge of the crater-ring continued towards the probable centre, then the height would have been somewhat greater, and if, on the contrary, the angle flattened then the height would have been correspondingly less. In this connection it should be noted that the flows on the eastern bastion (2997 feet) of Mount Herbert are inclined at an angle suggesting an origin near Akaroa and distant from Onawe some eight miles. Even if they rose in that direction at an angle as low as 3° it would mean that the summit of the volcano was 2,300 feet higher than the summit of the bastion—that is, it exceeded 5,000 feet. This is as accurate an estimate as facts appear to warrant. The same method of calculation would give Lyttelton volcano a height of between 3,000 and 4,000 feet, so that Akaroa was the greater.

And there is a reason why the two volcanoes were probably higher, although their forms remained the same. Owing to a lowering of the land relative to the sea after volcanic activity declined or had actually ceased, the present height is less than it was formerly. The precise amount of lowering is not known, but earlier in this revision (Speight, 1943, p. 15) evidence is given that in the Lyttelton area, and inferentially in that of Akaroa as well, the land formerly stood at least 700 feet higher than at present, therefore it is probable that the Akaroa volcano formerly had a height approaching 6,000 feet. Thus it did not reach the height of the present cones of Ruapehu or Egmont, though, allowing for the wide area that it covers, its dome-shaped form might give it a greater volume.

4. SPECIAL LOCALITIES.

(1) Scenery Nook.

A specially interesting landscape feature, with striking colour effects, occurs in an indentation of the southern coast about a mile and a-half west of the harbour entrance; this is known as Scenery Nook. Exposed in the face of the cliff on the western side are well-stratified beds of ash, scoria and agglomerate, reddish in colour, above 100 feet in thickness, bent into a syncline, and capped by the ordinary basalt; an underlying basalt is exposed at the base of the beds. They are penetrated by dykes, presumably trachytic, some not oriented according to the usual arrangement of Akaroa dykes to be referred to later. The occurrence is possibly a parasitic cone or outburst on the flanks of the volcano during its construction, which has been covered up by subsequent outpourings from the main centres of eruption.

(2) Dam Rogers Cliff.

This is the most striking scenic feature on the shore of the harbour. It lies about a mile inside the north head. The cliff is vertical, 500 feet in height, and a solid flow of basalt occupies half the face; this is inclined at an angle of about 7°; narrow bands of scoria lie beneath it and divide the flows at lower levels. In these the sea has driven caves. Towards the entrance to the harbour the flows are numerous, only a few feet in thickness, separated by thin scoria and ash-beds which are inclined seaward at low angles.

(3) Little River Valley. (Panorama and Plate 31.)

The panorama has been included in order to give some idea of the general features of the valley. The two trailing spurs which converge towards the floor of the main reach give it a form entirely different from that of the caldera of Akaroa, a difference due primarily to the fact that, while the tributary valleys of the former have been eroded in beds dipping initially in the direction of the valley profile (Plate 31), those of the latter, except near the entrance to the caldera, have been eroded across the scarp of the beds.

Nevertheless, the possibility that Haast and Hutton might be correct in attributing the major features of Little River Valley to explosive action was always kept in view when examining the area from a stratigraphical standpoint. If they were correct some of the flows should show a quaquaversal dip, including directions towards

Akaroa; and this does not occur. The outcrops of flow so strikingly developed on the eastern side of the valley indicate an origin in the direction of Akaroa, and the rocky knobs which stand up like the vertebrae of a backbone on the skyline are the remnants of the upper edges of flows oriented to that centre and not to Little River. The inclination of a well-defined outcrop on the northern flank of Saddle Hill, seen clearly from both Akaroa and Little River, has an appearance suggesting that it might have come from a centre located in the upper part of the latter valley; but a careful examination on the spot discloses this to be illusory and that it really came from a locality in the direction of Onawe. Of course the flows shown in Plate 31 could have come from either centre, but other circumstances rule out Little River Valley as a possible source.

In one or two cases the outcrops of flows on the western side of the main valley at an intermediate level show little inclination, but in my opinion these are accidental features dependent on the form of the surface over which the lava flowed. There is a possibility that some of the lower beds were derived from the Lyttelton centre, and the level outcrops can be thus explained, since they would in that case be on the very periphery of the cone where flat beds might be expected.

5. The Dyke System. (Plates 33 and 34.)

The dyke system of Akaroa is analogous to that of Lyttelton. There is the same radial arrangement in the outer parts of the area and the same criss-cross pattern near the centre, the peninsula of Onawe, in Akaroa Harbour, corresponding with Quail Island, in Lyttelton Harbour, as the locality on which the outlying dykes in general converge. A great many show on the shore-platforms round the upper reaches of the harbour and specially so in the vicinity of Onawe. Fewer are visible on the shore lower down the harbour, and there are short reaches where they are quite absent. For example, they do not show at all in the western part of the massive basalt that flanks Otipua Hill for a quarter of a mile on its south side, though a few, both trachytic and basic, occur near the eastern end. They are very rare beyond a line extending across the harbour from Green Point to Wainui Island, though they are reasonably common near both those places. This is no doubt partly due to the fact that the shoreline in the lower reaches of the harbour is parallel to the strike of the dykes in that sector, so that only those departing from the general direction have a chance to show, except where they cut irregularities in the line of the coast. Some show on the external cliffs, as at Scenery Nook, and a high promontory, some two miles east of the harbour entrance, is called Dyke Head. They are, however, practically absent from that stretch of the periphery extending westward from Birdlings Flat, where the ends of the spurs were once cut back by the sea.

A very limited number appear on the exterior of the cone or in cuttings of the Summit Road and of the roads on the flanks of the volcano. There is nothing at all like the great succession round the Lyttelton tops, although there are certain sections where they occur sparingly. For example, they show on the road to the Light-

house, one more than 15 feet thick, and three trachyte dykes occur within a chain on the Summit Road at the head of Okains, also basic dykes appear occasionally on Cameron's Track, which passes round the north side of Lavericks Peak, and on the road to Peraki. Two basic dykes cut across the Saddle Hill ridge, one about a chain north of the trig, another some ten chains away to the south-east, while a large trachyte dyke, over 18 feet thick, and oriented to Onawe, crosses the south-eastern shoulder of the hill. There is, however, a marked deficiency in number as compared with Lyttelton. This may be due to an actual paucity, but other factors afford reasons for the small number.

(1) The more complete covering due to weathering as distinct from erosion may partly explain the small number of Akaroa dykes exposed.

(2) Owing to its more youthful age it has not been exposed so long to erosion, and therefore the ribs of the volcano, so to speak, have not been exposed to view.

(3) The force behind the intrusions may not have been competent to raise a large number to the neighbourhood of the crest of the Akaroa crater-ring, the effort dying out at lower levels, and particularly so since the rocks of which the cone has been constructed, judging from available exposures, are more resistant to rupture than those of Lyttelton and contain a lower percentage of fragmentary material. Haast has pointed out that dykes of the Lyttelton area frequently do not reach the present surface (*op. cit.*, p. 340 et seq.), and he mentions that five of the dykes which cut the floor of the Lyttelton Tunnel did not reach the roof. In his explanation he stresses the fact that many of the dykes not exposed on the present surface of the ground did actually see the light when they were injected, but that subsequent flows covered up their outcrops. This serves to explain the occurrence of a dyke on the western side of the entrance to Akaroa Harbour. Any or all of these explanations just cited may account for the small number of dykes seen on the exterior and interior slopes of the Akaroa cone above the shoreline. There is perhaps a tendency to regard the present *general* outline of the cone as representing its maximum development and the dykes now visible as having at the time of their intrusion reached the height they now show and not reached higher, whereas a considerable stripping of their projection upwards and of the overlying rocks has taken place.

Though there is a dominance of trachyte in this area, basic dykes certainly occur. Analyses have already been published by the author (1923, p. 149, and 1940, pp. 71–2), and additional ones are given on page 243. There are four occurrences of trachytoid intrusions not already mentioned and worthy of special notice. Two of these lie on the eastern slopes of the volcano—viz., (i) Panama Rock and (ii) View Hill, and two on the western side—viz., (iii) the Devils Gap, near Peraki, and (iv) the Pulpit Rock in French Farm Valley, the last on a slope facing the harbour.

(1) The Panama Rock. (Plate 33.)

This lies on the eastern side of the Panama Track, a little-used road connecting Okains Bay with Le Bons Valley across the upper levels of Lavericks Valley. When viewed from the Summit Road at the head of Le Bons (Plate 33), it presents a most striking appearance, and it rises from the crest of the ridge north of Le Bons like a typical volcanic plug, with a long trailing dyke stretching from it in a south-westerly direction. The general level of the ridge from which it rises is about 1,600 feet, and the mass itself reaches a height of 1,891 feet. It extends about 15 chains in a north-easterly direction, almost in a line with the dyke, and its slopes are precipitous on all sides but the north-east; its summit is fairly even and of varying width, with a maximum of about four chains. At its north-eastern end it slopes down rather rapidly, and does not cross the road along the Lavericks-Le Bons ridge to the east-north-east. On the north face it shows rudely columnar structure in addition to vertical partings.

The exposed terminal mass appears to be an expansion of the end of a dyke which fed it, and the material discharged from the fissure apparently mushroomed out over the adjoining surface, thus accounting for the great volume exposed. Near it the dyke is over a chain in width, but half a mile away down the track to Le Bons it narrows to about 50 feet, and after another 10 chains it does not show on the surface at all, and it cannot be recognised on the Summit Road towards Onawe where it should occur if the alignment continued.

The terminal mass may represent either (i) the summit of a subterranean dome of laccolitic character, or (ii) a volcanic neck, or (iii) a volcanic plug. In the first case, the present exposed position would require that the former cover had been removed by subsequent erosion; but I do not think that the existing form of the Lavericks-Le Bons ridge in the vicinity of the mass is substantially different from that obtaining when the intrusion took place. It must be admitted, however, that I have not examined the ground at Trig. Q (1,865 feet), a mile east-south-east of the Panama Rock, or Le Bons Peak (1,641 feet), a mile and three-quarters away to the east, both on the ridge just mentioned. In the second case there is no sign of the remnant of lava flows or fragmentaries usually associated with a neck, and the petrological character of these should be related to that of the central mass, and therefore easily recognisable. These two hypotheses are considered unsatisfactory, and so there remains the third—viz., that the rock is a volcanic plug. It will be found to answer the description of a plug given by Daly (1914, p. 131), which is as follows: "In exceptional cases the highly viscous lava of relatively cool vents has exuded in quantity sufficient to form distinct domes at the surface, and notably overlapping the limits of the vents. These domes have grown *endogenously,* as bodies of unbroken, massive lava." This statement seems to agree with Stearns' (1942, pp. 21–22) description of the mode of formation of the bulbous domes of Maui, and it certainly fits in with the phenomena to be seen at the Panama Rock.

Another point to be considered is whether or not the mushrooming over the adjacent surface occurred all along the line of the dyke or was located only near its termination. Unfortunately this cannot be determined for certain, since the dyke is exposed at lower and lower levels as it continues to the south-west, and any expansion at the surface as it was originally may have been removed by subsequent denudation. But there is no remnant that I have seen which might suggest a former expansion. I therefore conclude that this bulbous dome, to use Stearns' term, was located on the present ridge at the end of the extension of the dyke towards the north-east.

An analogous mushrooming out on the margin is given by the dyke called Dover Castle on the western side of Heathcote Valley in the Lyttelton area. This has a somewhat peculiar chemical and mineralogical composition with trachytoid affinities (Speight, 1923, pp. 136–37).

The Panama Rock has a definite fissile texture with a glistening appearance on the fractured surface, and this is specially to be noted where the material has expanded over the adjacent rock, but it shows distinctly all over the summit. The surface is marked with definite indentations, with the cores of the projections formed of harder rock. Petrologically it is a soda trachyte, as is disclosed by the analysis given herewith.

Note.—No attempt is being made to give a full petrographical description of the rocks mentioned here and subsequently. That is left to a more competent petrologist.—R. S.

Analyses of Trachytes.

Analyst: F. T. Seelye.

	No. 1.	No. 2.
SiO_2	62.36	62.82
Al_2O_3	17.07	17.10
Fe_2O_3	2.97	2.49
FeO	2.09	2.54
TiO_2	0.33	0.34
MgO	0.26	0.29
CaO	1.40	1.29
Na_2O	6.48	6.75
K_2O	5.40	5.16
H_2O+	0.72	0.56
H_2O-	0.76	0.51
CO_2	nt. fd.	trace
P_2O_5	0.07	0.11
V_2O_3	nt. fd.	nt. fd.
ZrO_2	0.03	trace
Cr_2O_3	nt. fd.	nt. fd.
MnO	0.07	0.08
NiO	nt. fd.	nt. fd.
BaO	0.06	0.03
* SrO	$<$ 0.01	0.002
S.	0.03	0.01
Cl.	0.01	trace
	100.12	100.08

* Determined spectrographically directly on a sample of the rock.

C.I.P.W. Norms and Symbols.

	No. 1.	No. 2.
Q.	1.47	0.94
or.	31.89	30.50
ab.	54.79	57.10
an.	1.59	1.14
di.	3.29	3.86
hy.		0.93
wo.	0.41	
mt.	4.26	3.61
il.	0.63	0.66
ap.	0.17	0.27
pr.	0.05	

No. 1. Soda Trachyte, Panama Rock, Le Bons Bay. I". 5. 1. (3) 4. Nordmarkose.

No. 2. Soda Trachyte, Devils Gap, Peraki. I (II). 5. 1. "4. Nordmarkose.

Under the microscope the rock appears to be composed of short laths of alkalic felspar some characterised by denticulate margins, like the anorthoclase of a bostonite. Scattered through an even-grained mesh of this material are numerous short laths of greenish, pleochroic, aegerine-augite. Phenocrysts are rare and the few I have seen are of sanidine.

Crossing the junction of the roads just north-west of the Panama Rock is a basaltic dyke, one of the few visible on the external surface of the cone, and its visibility results entirely from excavations in forming the road.

(2) View Hill.

View Hill forms an elevated ridge rising to 2,491 feet, oriented north-east and south-west, about half a mile in length, near the proximal end of the divide between Little Akaloa and Okains valleys. The summit of the ridge is fairly even except for a slight depression which cuts across about a third of the distance along it from the north-east. Passing along it from this direction the following sequence is exposed:—

(a) *Basalt*, the remains of a solid flow dipping north-east, with approximately vertical columnar structure, and probably originating from Akaroa.

(b) *Fragmentaries*, containing scoriaceous masses, exposed on the surface of the ridge for several chains, thickness uncertain They mark the depression in the crest of the ridge just referred to. Their development suggests the possibility that they mark the position of a parasitic cone.

(c) *Basalt*, differing in texture from (a). Contacts with (b) and (d) are obscured, though it probably overlies (b) and underlies the margin of (d).

(d) *Trachyte*, forming a long oval dome, about 15 chains in length and 10 in width, oriented in the direction of Onawe; the summit is slightly inclined in this direction, and the slopes at the margins are only moderately steep, and are covered with grass; exposures are rare and the contacts obscured.

(e) *Basalt* appears on the steep slopes at the western end of the ridge, having come apparently from the direction of the Akaroa centre. The remaining part of the ridge to the south-west is narrow, with interstratified flows of basalt and fragmentary material. It furnishes a typical example of the destruction of inter-valley ridges near their proximal ends and the semi-isolation of a planeze.

The trachyte of section (d) is the interesting feature of this occurrence. At either end of the exposure the rock is brownish in colour and very flaky, being reminiscent of the fissile material of the Panama Rock, but almost half-way along there is a small exposure of more massive form, just rising above the grassy surface, very much lighter in colour, somewhat vesicular in texture, with some of the vesicles partially filled with an undetermined amygdaloidal mineral, softer than glass and not acted on by acid. Both facies of the rock are aegerine-augite trachyte, the brown variety containing more augite than the light-coloured one.

The oval, dome-shaped form of the trachyte mass suggests an analogy with the bulbous domes of Stearns. It is certainly an intrusion or results from one, but the contacts are obscured and its relationships to the associated basalts cannot be determined for certain. The inclination of the lava flow at the eastern end of the ridge—presuming that it originated from Akaroa—suggests that it once continued over the trachyte mass, and that the cover has been subsequently removed by erosion, but how much was removed cannot be said There may be some analogy between this case and those described by Daly (1925) in his account of the geology of Ascension Island, where viscous trachyte masses are very intimately associated with basalt eruptives (pp. 23–38). Both the form of the mass and the probable existence of a former cover indicate a laccolitic origin, the longer axis of the dome corresponding possibly with the direction of a short feeding dyke oriented to Onawe. It does not continue to the south-west beyond the end of the ridge, though it may continue after some break to the north-east. It is possible, but not probable, that the tilt of the basalt at the eastern end of the ridge may be due to a warping of the overlying beds resulting from the intrusion, but there is no sign of such warping at the western end.

I was not able to locate the dolerite previously referred to (1924, p. 262) as coming from this locality. It contained greenish augite, brown hornblende, a little mica, and much apatite. This may indicate the presence of another intrusion to the north-east, since the rock is entirely different from any known to occur in the Akaroa area or on the remaining portion of Banks Peninsula.

(3) The Devils Gap. (Plates 33 and 34.)

An analogous trachytoid intrusion of massive size forms the eastern wing of the Devils Gap, a striking landscape feature on the western side of Peraki Valley on the southern flank of the volcano. The western wing has been referred to earlier in connection with estimates of the former height of the cone. This massive capping of basalt, one hundred feet thick, the summit 2,412 feet above sea-

level, stretches down in a southerly direction along the middle part of the ridge dividing Peraki and Te Oka valleys. The intrusive mass lies east of the basalt, extends down the slope to the east (Plate 33), and after an interval obscured by soil and surface deposits, appears again as a massive buttress nearer the floor of the valley (Plate 34), the whole occurrence forming the most extensive example of this class of intrusion that I have come across on the peninsula.

The upper part seems to be plastered, as it were, on the side of the valley, suggesting an orientation towards Onawe, but it cannot be traced uphill along the ridge more than a few chains beyond the end of the basalt, where a very limited exposure occurs in the tussocks, and, further, the great mass at lower levels on the side of the valley discounts this apparent orientation, and indicates an extension along an east and west axis. Had the Peraki Valley been eroded when the intrusion took place the lower part might have been regarded as a viscous tongue directed downhill from a dyke oriented to Onawe from near the position of the trachyte mass which forms the eastern wing of the gap, but it does not seem likely that the intrusion took place at such a late date in the history of the volcano. The total length of the exposure in an east-west direction is about half a mile, and its width over 15 chains, but I have seen no clear-cut contact between it and the associated flows and fragmentaries. The basalt mass and the beds beneath it about two chains away from the trachyte across the gap, show no disturbance as a result of the intrusion. No feeding dyke, like that at the Panama Rock, can be seen, and it is apparently more closely related to the occurrence at View Hill, though it does not exhibit the dome-like form of that intrusion. Perhaps this difference is due to modification of its upper surface when the Peraki Valley was eroded, for I cannot think that its intrusion occurred after that valley had taken on its present form.

Also it cannot be said for certain that the intrusion reached the ground surface at the time of its injection, though the present situation implies that it did not do so. It was probably laccolitic in form and the erosion responsible for the excavation of Peraki Valley has been the reason for the exposure to view of this sub-surface intrusion.

The rock is resistant in the mass though the surface exposed to the weather is soft. The lower part exhibits the vertical parting characteristic of the Panama Rock. Analysis No. 2, p. 243 shows it to be a soda trachyte closely related to this rock. Under the microscope occasional phenocrysts of sanidine (? anorthoclase) and aegerine-augite appear in a base of alkali felspars laths and stumpy forms of aegerine-augite. Thus its mineralogical composition is analogous to that of the Panama Rock, though it differs slightly in texture, notably in the form of the felspar of the base.

(4) The Pulpit Rock. (Plate 34.)

This is the last of the four large trachytoid intrusions to be mentioned. It stretches across the upper part of the French Farm Valley for over a quarter of a mile, and its summit lies at a height of about 1500 feet. The stream occupying the floor of the valley has cut deep into the rock dividing the exposed portion into two unequal

parts but not exposing the base. The southern part forms a bold landscape feature and rises precipitously for 250 feet above the ground fronting it; this part is known as the Pulpit Rock. The northern part is thinner and less striking; it exhibits a closely-spaced and parallel lamination, perhaps due to chilling by the underlying basalt when the mass was injected. The surface deposits have so obscured the contacts that a satisfactory conclusion cannot be arrived at concerning the form of the channel up which the magma came or what was the original shape and extent of the mass. This uncertainty as to its original form is accentuated by the erosion it has suffered during the formation of the caldera, and its exposure to the light of day may be due to that cause. It appears to be oriented on approximately N.N.W.–S.S.E. lines, and it probably extended in the former direction across the top of the ridge dividing French Farm Valley from the western branch of Okuti Valley; for, after an obscurity due to the covering of soil, trachyte in position appears for nearly a chain close to the old yards on the summit of the ridge (height 1,815 feet), and scattered fragments continue on the surface for more than five chains further into the upper part of Okuti Valley. This rock is a variant of that of the Pulpit Rock, and may be a marginal facies of it; it is a dark-coloured, very hard, fine-grained aegerine-augite trachyte.

The basalt flows above the main mass in the direction of Saddle Hill do not appear to have suffered any dislocation or warping from the intrusion of such a thick body of rock, and this suggests that it had flowed out at the surface as a bulbous dome and been covered up subsequently by material discharged as the cone was built up further. All the same it is doubtful how far away from it such a mass would cause warping in pre-existent flows. But if the exposure on the crest of the ridge near the yards does link up with the mass in the valley, then this explanation becomes unsatisfactory, especially as the exposure near the yards is interstratified with basalt flows at a higher stratigraphical level, indicating an upward transgression through them of the intrusive mass. The variation in facies can then be easily explained as due to the smaller size of the intrusion at higher levels or to more effective chilling of the margins.

However, the occurrence near the yards presents resemblances to another trachyte mass, which occurs on the crest of the ridge, height about 2,250 feet, about three-quarters of a mile to the south. This outcrops immediately above the Pulpit Rock, on the downhill side of the prominent escarpment of basalt and its underlying breccia which marks the northern flank of Saddle Hill; the dip of this basalt is between 5° and 7°. The trachyte outcrop extends along the crest of the ridge for about four chains. It reaches down the slope towards the Pulpit Rock for about a chain, when an undisturbed basalt in position cuts it off. The relation of the mass to the basalt of Saddle Hill is obscure; on the ridge to the north—that is, toward the yards, it is also cut off by basalt breccia and flows in position; while on the slope towards Okuti Valley the ground is soon covered by soil and debris, and the true extent of the mass in that direction cannot be determined, but basalt on both sides narrows the exposed width

to less than two chains. It does not appear to have any close connection with Pulpit Rock, though this absence of connection may be illusory. The form of the occurrence suggests that it is a small, independent intrusion extending down the slope of the Okuti Valley from just beyond the crest of the ridge, or perhaps an offshoot of the intrusion at Pulpit Rock, as suggested for the occurrence near the yards. It does look something like a flow, but if so, it is the solitary case known from the area. Although the connection with the Panama Rock is not obvious, I think it represents an off-shoot from that mass.

The exposed surface is coloured brown owing to the oxidation of the ferrous constituent, and is marked by denticulations like those of the trachytes referred to earlier. The rock is very hard, dark-coloured, and is a fine-grained aegerine-augite trachyte, without phenocrysts or with very small ones, and with a base composed of much augite in stumpy laths and alkali felspars in short, rarely lath shaped forms. This description applies to the rock exposed near the yards further north on the ridge. The two occurrences thus differ to some extent from the Pulpit Rock, but such difference may be due to marginal chilling or to the relative smallness of the intrusions or extrusions, if indeed they are actual flows; the latter suggestion I do not endorse.

It is possible that others of similar character may ultimately be located on the slopes of Saddle Hill.

Since writing the above, I have observed from the upper slope of Saddle Hill a mass resembling the Pulpit Rock in appearance and with similar orientation, outcropping in the upper part of Wainui Valley, but was unable to examine it closely. The large trachyte dyke, referred to on page 241 as occurring in this locality, meets it at its south-eastern end, and may be genetically connected with it.

On the northern side of Reynolds Gully, on the south-western slopes of Saddle Hill, there is a massive upstanding occurrence of basalt, only a few chains in length and oriented towards Onawe. At first sight it looks like an intrusion, but at the base of the northern face basaltic breccia shows underneath the exposed mass, so no doubt it is a remnant of a thick flow of basalt.

Analyses of the smaller trachyte intrusions, belonging either to the basement beds or to those of the cone, as well as one of a basic dyke near the neck at Onawe, are given in two articles by myself (Speight, 1923, p. 149; and 1940, pp. 71–2). The composition of these trachytes dykes is closely related to that of the massive intrusions.

The four main trachyte intrusions have much in common. They are all aegerine-augite trachytes with similar mineral and chemical composition, although they differ slightly in texture. All, except View Hill, have analogous minor surface features such as denticulations, and major features such as pronounced vertical partings. The flaky outcrops of the limited exposures of View Hill suggest that it might also have similar features if the surface had been similarly exposed to the weather. The intrusions are all short in length, of great relative width, and all but that at the Devils Gap dome-like in form. These resemblances point to a similar origin, and this has already been

considered at some length in connection with Panama Rock, and perhaps the evidence of this well-exposed occurrence may furnish the clue to the origin of the others—viz., that they represent bulbous expansions, to use Stearns' term, of relatively short dykes, either extruded on the surface or they are laccolitic expansions at depth. In no case have I come across any evidence of alteration of rocks or faulting in their vicinity.

The formation of bulbous domes composed of soda-trachyte on the Island of Maui, Hawaii, is attributed by Stearns and Macdonald (*op. cit.* pp. 310–11) to differentiation arising partly from crystal settling of the heavier elements such as augite and olivine in the sub-surface magma chambers and partly from the transfer of the volatile constituents, particularly the alkalies, to the upper chambers feeding these domes The general similarity in the character of the igneous rocks and of the forms of the Hawaiian volcanoes to those of Banks Peninsula is interesting in this connection, and suggests that these intrusions may be attributed to similar causes

This explanation adopts and amplifies that given by Daly (1925, p. 79) when accounting for the numerous trachyte domes of Ascension Island and their association with its basalts. However, the forms of the Akaroa intrusions appear to resemble more closely those of the trachyte masses noted in the same author's account of Saint Helena (1927), as, for example, his drawing of Speery Islet (p. 53) and his account of Great Stone Top (p. 55) which he attributes (p. 91) to "emanation of the alkaline magma through a dyke fissure." In the case of Panama Rock both the dome and the fissure are plainly visible, the latter indicated by the dyke.

The association of trachyte with basalt is so common, especially in the islands of the Pacific, that mention of particular cases is unneccessary. However, the hypothesis just referred to may serve to explain the formation of trachyte dykes as well as bulbous domes at various stages in the history of a basalt volcano. It is inconceivable that all the dykes were injected at one stage in the development of the volcano. If it be granted that they have been discharged from magma chambers at varying intervals, some coming out on the ground-surface and suffering erosion before they were covered up by subsequent eruptions, their infrequency at higher levels and their great number at lower levels will easily be explained. In the case of Akaroa I have not come across types intermediate between trachytes and basalts, but in the Lyttelton area the whole suite which would result from differentiation in a magma chamber are well represented—trachytes, trachy-andesites, andesites, alkaline basalts, and ordinary basalts occurring. Perhaps a more complete examination will show that these intermediate types occur at Akaroa.

Besides the intrusions just mentioned there are no doubt others awaiting location. It was not found possible to examine all localities, promising or otherwise, and I feel certain that other occurrences as interesting as the four major intrusions just referred to will be discovered eventually, and those already mentioned examined more thoroughly. They undoubtedly suggest complexities not hitherto suspected in what has up till now been regarded as a simple composite volcanic cone.

6. Age of the Volcano.

Owing to the non-existence of sedimentaries in the basement beds of Akaroa one important criterion is not available for the determination of the age of the volcano, and so reliance must be placed very largely on comparisons with Lyttelton. At the head of Lyttelton Harbour there is the following sequence of beds in ascending order lying on an older series of volcanics which in turn rest on greywackes of Triassic age—(i) *Sandstones and greensands,* of Awamoan, that is, Mid.-Tertiary age; (ii) *Rhyolites and pitchstones;* and (iii) *Basic andesites and basalts,* of which the cone was built. Between each pair of these occurrences there was a period during which the lower set of beds was heavily eroded, and considering the intervals of time necessary to carry this out, it is reasonable to date the Lyttelton volcano from Late Tertiary times. Now, the basalt flows of Mount Herbert overlie the third series with marked erosional unconformity, and must therefore be of later date. It has been suggested earlier in this account that the Mount Herbert lavas come from the direction of Akaroa and possibly from Akaroa itself. If the latter supposition is correct then the Akaroa volcano must date from Latest Tertiary or even Early Pleistocene times. If the lavas did not come from Akaroa but from another centre in the same direction, such as Kaituna, then reliance must be placed on physiographic evidence as an age criterion, and this clearly indicates that Akaroa is much younger than Lyttelton, so that the age just suggested appears to be quite reasonable. It is unfortunate that no help in this difficulty is furnished by a comparison with the later volcanics of other regions of Canterbury, such as Timaru, Geraldine, the Malvern Hills, or View Hill near Oxford. The later rocks of these areas, though undoubtedly basic, differ in texture and composition from those of Akaroa, and must have been extruded under conditions and possibly at times differing from those of the Banks Peninsula volcano.

7. Surface Deposits, etc.

From time to time references have been made to occurrences of diatomite in the area under consideration, and one near Wainui has recently been described by Willett (1944, p. 90). It is extremely probable that small deposits may be located in the future, since temporary ponds must have been formed occasionally in times gone by, especially behind rock falls and landslips, but these cannot be of large extent, and their discovery will no doubt be largely a matter of chance On the slopes facing both ways near the saddle between Wainui and Peraki valleys lie areas favouring such deposits.

The soil covering of the western and northern slopes facing the harbour have been fully dealt with by C. S. and A. C. Harris (1939, pp. 1–10). A point of special geological interest is the distribution of loess. This forms deposits up to 50 feet thick near sea-level, the amount gradually declining at immediately higher levels, and then disappearing entirely, to be resumed on the flat ridges near the summit. This statement appears to be generally true not only on the internal but also on the external slopes of the cone. Plate 31 shows a thick deposit on the shore of Lake Forsyth. I can confirm the general truth of the statement that it may be thick on gentle summit slopes even up to heights of over 2,000 feet.

There is another matter which concerns surface deposits and the origin of the Akaroa caldera. If the basin has been formed by a great explosion then some remains of the material ejected should be found on the external slopes of the cone; but I have found no trace whatsoever. It is inconceivable that all the fragments necessarily produced by such an explosion and scattered in thick drifts could have been removed by denudation and leave not a trace behind. For this reason alone I consider the explosion hypothesis untenable.

Some consideration should be given to the possibility of earth movements following on the decline and extinction of volcanic activity, but there is no clear evidence of such. The irregularity in the direction and amount of dip to be observed on the shore-line round the middle and upper part of the harbour can be explained as resulting from irregularities arising from conditions obtaining during an earlier volcanic episode or immediately following it. A survey of the dip of the beds in the upper part of the cone gives no definite indication of incipient warping or other crustal deformation. Some of the lava flows round the crater-ring do exhibit at times a moderately steep inclination, but this is a purely local feature. The drowning of the harbour may indicate a settling of the land after volcanic action had ceased, but it more probably indicates a rising of sea-level following on the recession of the ice after the Pleistocene glaciation; and there is no reason why both factors should not have been simultaneously operative.

The shore-platforms round the harbour seem to be rather high to have resulted from marine erosion at present land-level, and it is possible that a slight rise has set in during recent times, but this amount cannot exceed a maximum of two feet.

The physiography and the origin of the landscape forms typical of the area, such as the mode of formation of the great basin which now occupies the heart of the volcano, and the erosional forms of the exterior surface, have been dealt with previously.

8. COMPOSITION OF LAVA FLOWS AND COMMENTS THEREON.

The Akaroa lavas—lying above the basement of plutonics, trachytes, and basic rocks—appear to be entirely basalts. Some criteria for differentiation of basalts from andesites would insist on some of them being assigned to the latter group, and these points will be mentioned later as individual cases are considered. From the mineralogical point of view there does not appear to be any feature occurring in the earlier rocks, such as the relative abundance of olivine, which is not matched in the later rocks, and the same applies to textures. While finer-grained types appear to be more common in the later flows, they occur quite freely in the earlier ones. In order to determine if there was any significant variation in chemical composition as extrusion proceeded, specimens for analysis were collected at various heights and in different localities, and these have been analysed by Mr. F. T. Seelye, of the Dominion Laboratory. Results already published include three from near sea-level (Speight, 1924, p. 260, No. 3; and 1940, p. 71, Nos. 4 and 5). The first of these, from just north of Duvauchelles Wharf, has a composition analogous to that of rocks at higher levels, although from strati-

graphical considerations it should perhaps be assigned to the basement rocks of the volcano; the second is entirely different and can certainly be assigned to the basement beds; while the third presents anomalies owing to the presence of a magnesian or iron carbonate which render it useless for comparative purposes. Nos. 1 and 2 on page 260 are of rocks from intermediate levels, the former from about 600 feet above sea-level, and the latter from about 1,600 feet, and they show close relationships in composition to those in the accompanying list. These two rocks were called andesites, following the criterion used by Washington for rocks on the andesite-basalt borderline. He calls andesites those basic rocks containing over 62.5 per cent. of normative felspar, and those with a less percentage he calls basalts. However, the Akaroa rocks which contain both labradorite and olivine, even if they have a higher percentage of normative felspar than 62·5 per cent. are called basalts in this account.

Analyses of Akaroa Lavas.
Analyst: F. T. Seelye.

	1	2	3	4	5	6
SiO_2	48.25	44.45	46.01	46.56	47.53	49.25
Al_2O_3	16.73	15.07	16.34	16.25	16.31	16.53
Fe_2O_3	3.86	3.37	3.63	3.37	4.10	4.16
FeO	8.00	9.76	8.81	8.73	8.10	8.11
TiO_2	2.65	3.05	2.86	3.17	2.93	2.45
MgO	3.96	7.77	5.19	4.92	4.65	3.28
CaO	7.45	9.70	8.62	8.84	7.87	7.14
Na_2O	4.46	2.77	4.07	3.85	4.02	5.05
K_2O	1.83	1.01	1.53	1.43	1.35	1.72
H_2O+	1.28	1.56	1.26	1.50	0.94	0.62
H_2O-	0.30	0.74	0.34	0.42	1.00	0.80
CO_2	0.17	0.12	0.03	0.02	0.03	0.02
P_2O_5	0.94	0.50	0.92	0.81	0.89	1.07
V_2O_3	0.01	0.028	0.02	0.025	0.018	0.01
ZrO_2	nt. fd.	nt. fd.	nt. fd.	nt. fd.	nt. fd.	nt. fd.
Cr_2O_3	nt. fd.	0.03	0.015	0.02	0.015	nt. fd.
MnO	0.17	0.17	0.18	0.17	0.18	0.21
NiO	nt. fd.	trace	0.01	trace	nt. fd.	nt. fd.
BaO	0.04	0.03	0.04	0.03	0.03	0.07
* SrO	$<$ 0.01	0.07	0.07	0.06	0.06	0.05
S	0.05	0.02	0.03	0.03	0.02	0.02
Cl	0.01	0.01	0.03	0.02	trace	0.03
	100.17	100.23	100.00	100.22	100.04	100.09

* Determined spectrographically directly on a sample of the rock.

C.I.P.W. Norms and Symbols.

	1	2	3	4	5	6
Q.						
or.	10.80	5.96	9.02	8.46	7.96	10.19
ab.	35.23	21.81	26.53	28.63	34.03	38.33
an.	20.25	25.70	21.80	22.84	22.47	17.35
ne.	1.34	0.88	4.29	2.13		2.38
di.	7.80	14.95	12.18	12.84	8.71	9.17
hy.					2.82	
ol.	9.90	16.34	11.51	10.44	8.36	8.41
mt.	5.51	4.88	5.21	4.84	5.95	6.04
il.	5.04	5.80	5.43	6.03	5.57	4.66
ap.	2.22	1.18	2.19	1.92	2.12	2.52
pr.	0.09		0.95	0.05		
(cc)	(0.39)	(0.27)				

No. 1. Basalt, Shoreline, Otipua Hill, opposite township, Akaroa. II. 5. 3. 4.—Andose.
No. 2. Basalt, Shoreline, Green Point. Akaroa. III. 5. (3) 4. 4.—Auvergnose.
No. 3. Basalt, Quarry near Hill Top, height about 1,600 feet. II (III). 5″. 3. 4.—Andose.
No. 4. Basalt, Okains Peak, height 1,880 feet. II (III). 5. 3. 4.—Andose.
No. 5. Basalt, Devils Gap, Peraki, height 2,400 feet. II″. 5. 3. 4″.—Andose.
No. 6. Andesite, Devils Knob. Birdlings Flat, near sea-level. II, 5, (2) 3, 4″,—Andose.

The following comments may be made on these results. First of all, it must be noted that earlier in this account it was suggested on strategraphical grounds that No. 1 might belong to the basement beds of the cone and its slightly more acid character than its position demands can be satisfactorily explained. The basicity of No. 2, from near sea-level and the earliest of the cone rocks of this series, confirms the description already given (Speight, 1924, p. 262), and it accords with the fact that blebs of olivine up to half an inch in diameter show in the hand specimen. No. 3, from a quarry near the Hill Top (height 1600 feet) is an undoubted olivine basalt, containing 4.40 per cent. of normative nepheline. Although the slide does not respond as a whole to staining, certain small anisotropic patches of irregular form do take the stain, and they may perhaps be nepheline. No. 4, from Okains Peak, is an olivine basalt containing both olivine and labradorite, as also is No. 5, from the Devils Gap, although it contains over 62.5 per cent. of normative felspar. No. 6, from Birdlings Flat, is the most interesting occurrence. In the hand specimen the rock is fine-grained, with definite flow structure, and with the peculiar grey tint that sometimes marks an alkaline basalt. Under the microscope it appears to be composed of a mesh of andesine laths, augite grains and laths, little olivine in small grains, but phenocrysts are practically absent, those present being of untwinned felspar (andesine) and little larger than the laths of the base. Some small rectangular forms that respond to staining may be nepheline. This rock is certainly the latest of those listed, and it was discharged towards the close of the Akaroa volcanic episode. Further it presents an interesting parallel as regards composition to the latest flow on the summit of Mount Herbert, classed as oliogoclase andesite (*op. cit.* pp. 252–3, No. 4, and p. 257). The similarity in composition, etc., serves to strengthen the suggestion made earlier that the flows of Mount Herbert may have come from the Akaroa centre. Of course this similarity may be only a coincidence, but taken in conjunction with other evidence it is certainly suggestive.

Leaving out No. 1, since there is some doubt as to its true stratigraphical position, there is a steady increase in acidity from the earlier flows to the later. However, the two specimens from intermediate levels mentioned earlier present some anomalies. No. 2 from 600 feet on the Barrys Bay Road fits in quite well, although it would be called an andesite according to the Washington criterion. But No. 1. from 1,600 feet on the Stony Bay Road, is more acidic than the rock from the Hill Top at approximately the same height. All the same it fits in quite well before the rock from Okains Peak and that from the Devils Gap. So the statement appears to be fairly accurate.

I wish in conclusion to express my indebtedness to various people. First of all, I should like to thank Dr. Henderson, Director of the N.Z. Geological Survey, for his kindly interest, and especially Mr. F. T. Seelye, of the Dominion Laboratory, for his excellent analyses, the last of many such which he has done at my suggestion in connection with various investigations I have undertaken during the past few years, and I wish to express my sincerest appreciation of his valuable help. I have also to thank Miss Thelma Kent, A.R.P.S., and Professor Bartrum for photographs; Professor Cotton for suggestions

and the loan of literature; and, finally, Mr. F. O. Waymouth, for much assistance in connection with transport to remote corners of the Peninsula.

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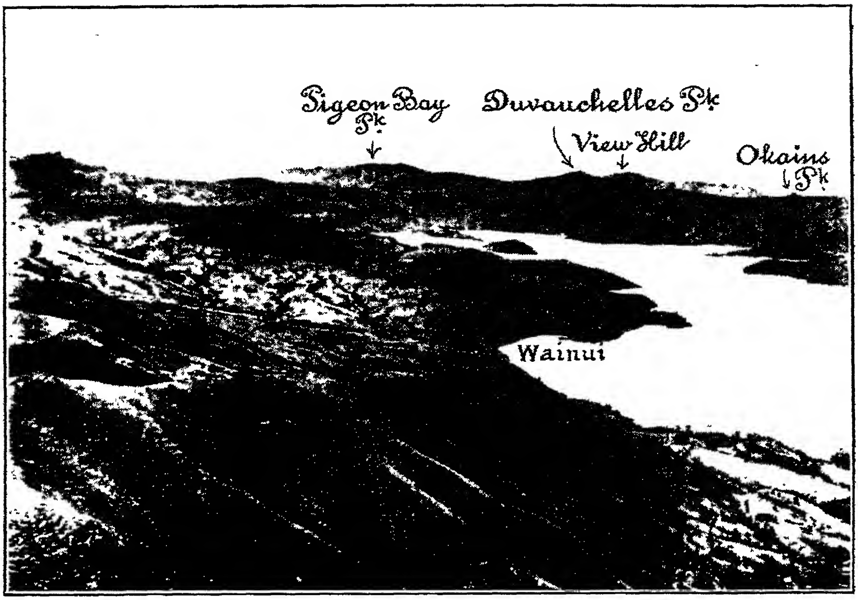
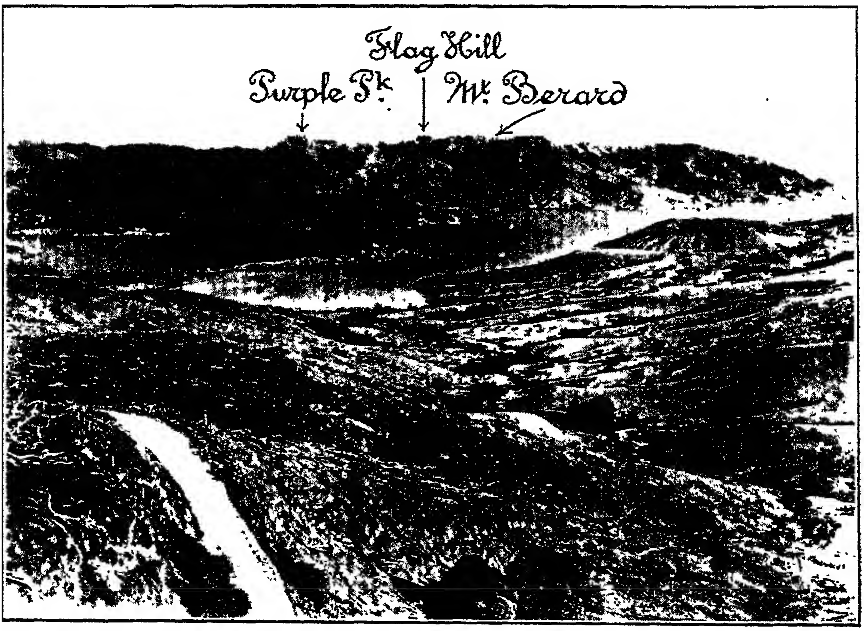


Akaroa Caldera from the summit of Mount Bossu, view looking north; Wainui in the foreground; Duvauchelles Peak, View Hill, and Okains Peak in the distance.



Akaroa Caldera from the slopes of Rocky Peak, view looking south-east; Barrys Bay and Onawe in the middle distance; the harbour entrance in the far distance on the right.

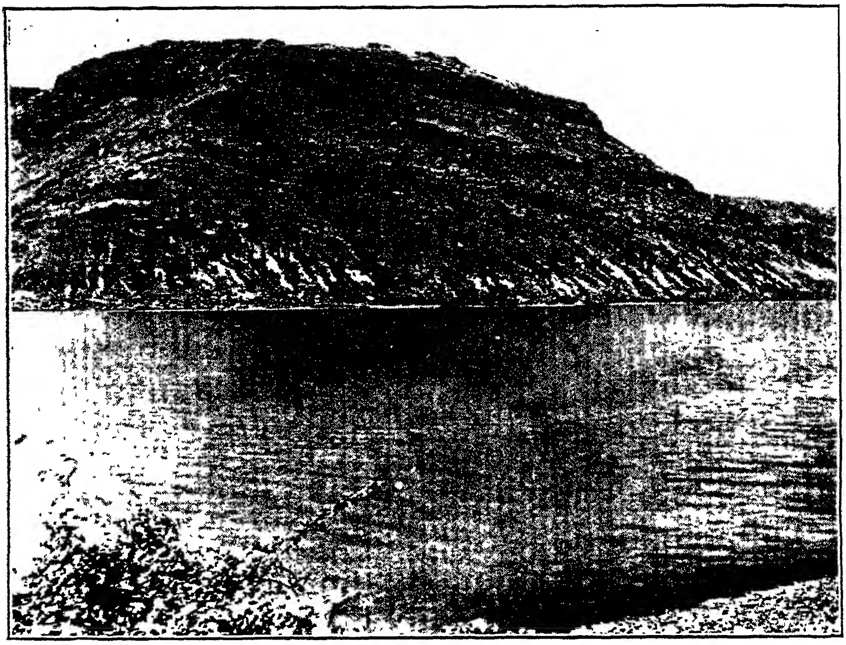


Photo: Miss Thelma Kent.

Eastern ridge of Little River Valley, view looking east across Lake Forsyth. Inclined lava flows, originating from Akaroa, show on the hillsides, and gullied slopes cut in loess, show just above the shore of the lake.

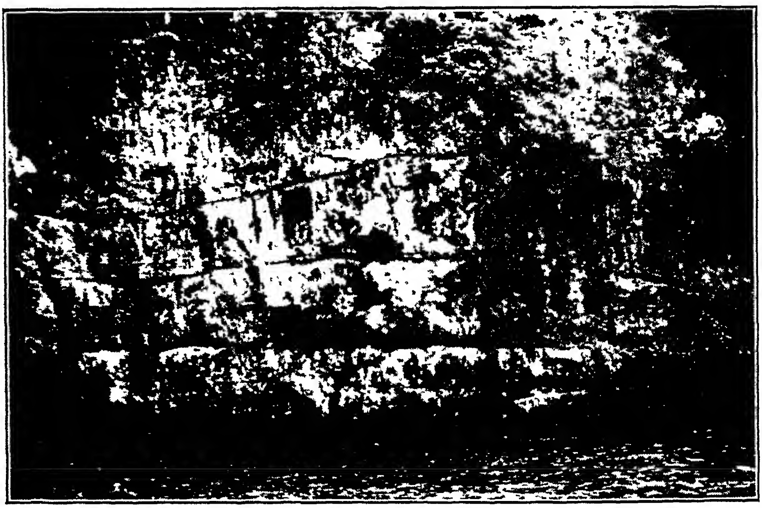
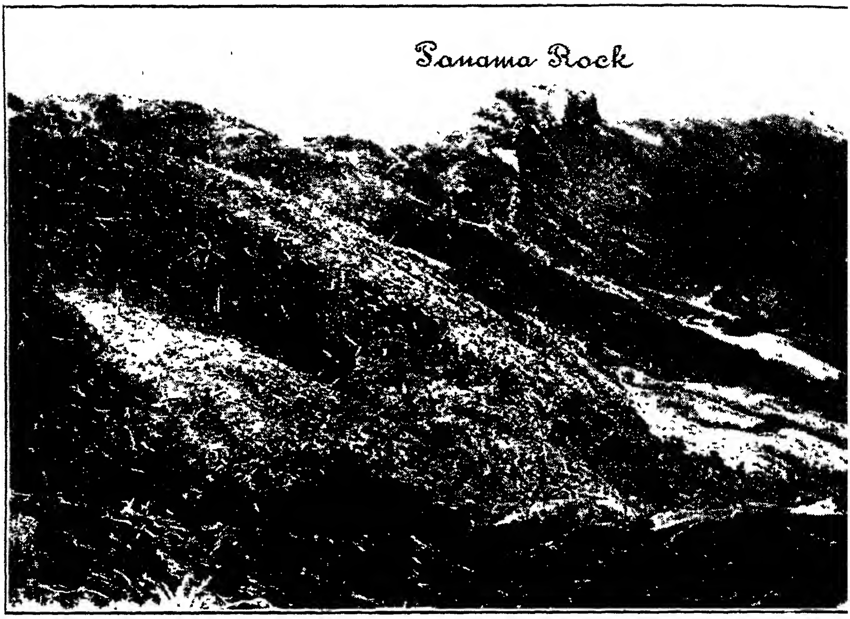


Photo: J. A. Bartrum.

Thin-bedded flat lava flows, on cliff near Dam Rogers.

Photo: Miss Thelma Kent.

Panorama of Little River Valley, taken from Te Oka Saddle, view ranging from west to north. Main valley in the middle distance; Western Valley beyond it in the distance; Puaha Valley behind the ridge in the middle; Okuti Valley in the foreground. The ridge in the left foreground is merely a bastion extending a short distance from the eastern wall of the valley. It will be seen that this landscape is entirely different from those shown in Plate 30.



Panama Rock, with dyke stretching south-west from it; view taken from the Summit Road at the head of Le Bons Valley.

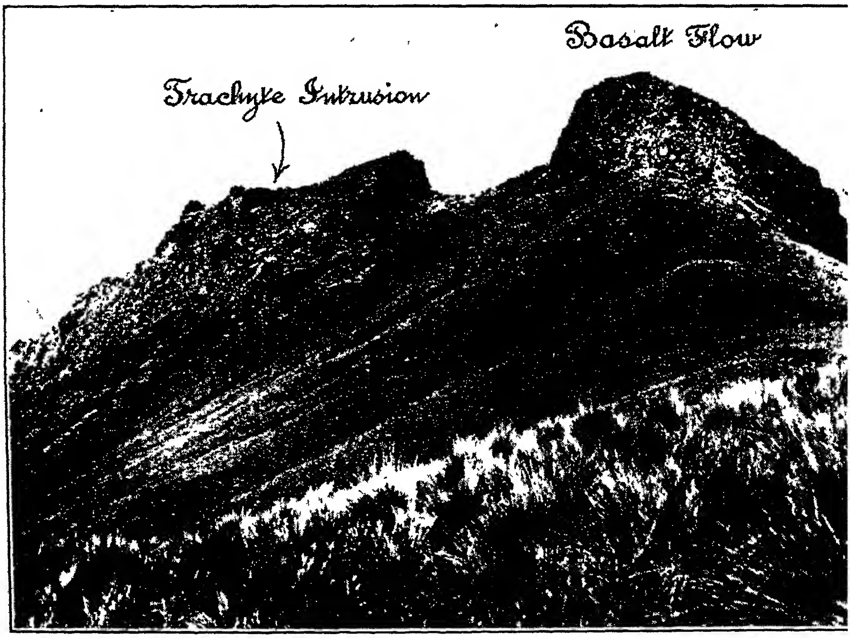
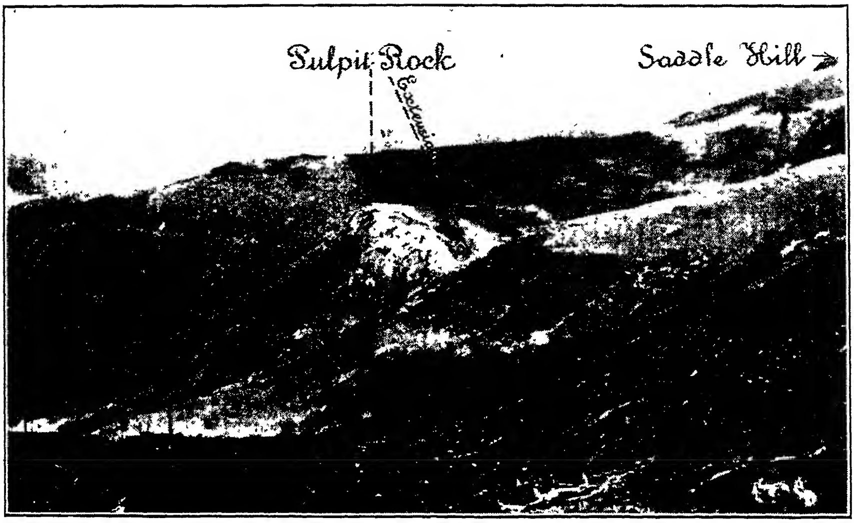
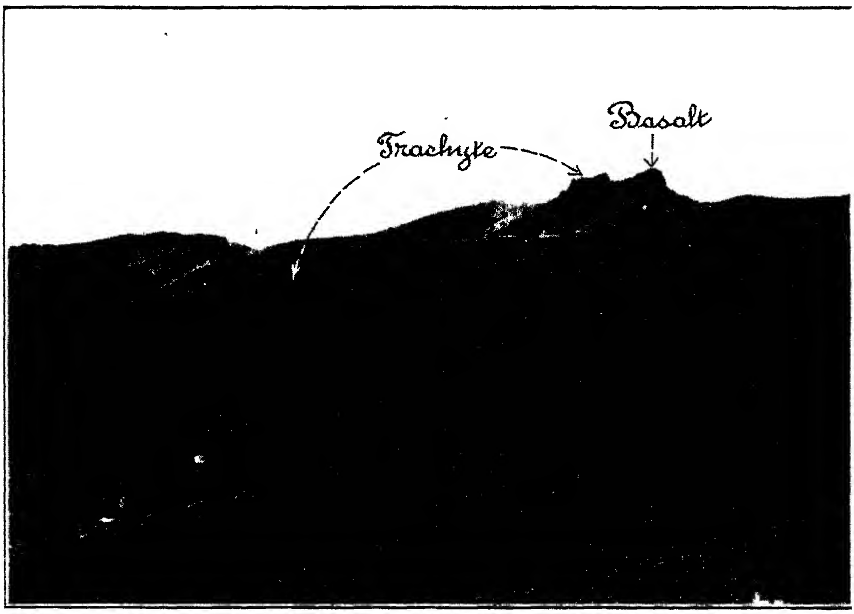


Photo: Miss Thelma Kent.

Devils Gap, looking south-east. Trachyte intrusion on the left, and massive basalt flow on the right.



Pulpit Rock, view looking south-east from Okuti Ridge near the yards; Saddle Hill to the right; the extension of the rock to the north-west lies under the face covered with scrub.



Trachyte intrusion on the west side of Peraki Valley; Devils Gap at the top of the picture; trachyte bastion towards the floor of the valley below the Gap. View from the east side of Peraki Valley, looking south-west.

To follow plate 33.

Transactions of the Royal Society of New Zealand,
Vol. 74, Part III, pp. 255-272, Plates 35-37.

New Zealand Fossil and Recent Cardiidae (Mollusca).

By J. MARWICK, N.Z. Geological Survey.

[*Read before Wellington Branch, July 13, 1944; received by the Editor, July 14, 1944: issued separately, December, 1944.*]

I. GENERAL.

In New Zealand, as in most places, the generic name *Cardium* has always been used in a very wide sense, and poorly preserved fossils are likely to require its continued use. For those species however, of which we know adequate details of sculpture and hinge, more restricted generic grouping must be used if we are to obtain from them the stratigraphic and distributional evidence that they offer. The now generally accepted type of *Cardium,* the Recent Indo-Pacific *C. costatum* Linné (designated by Children, 1823) has strong, high, sharp ribs. No relatives at all close are known from New Zealand, so the use of the genus here can only be in a family sense.

Of the two Upper Cretaceous species figured by Woods (1917, plate 18, figs. 3, 4, and 5) as *Cardium* spp., the original of fig. 3 must still remain thus vaguely designated, little further evidence having been found. The specimens of figs. 4 and 5, however, belong to *Ethmocardium.* The other Cretaceous species are all related to *Lahillia* and have been classed in a separate sub-family Lahilliinae (Fin. and Marw., 1937).

In her most useful summary of the Cardiidae, Dr. Myra Keen (1937, p. 13) excluded *Lahillia* from the family, suggesting its relationship to *Thetironia* Stoliczka. Much uncertainty has prevailed as to the family affinities of *Thetironia,* the general tendency being to put it in the Veneridae. This was done mostly without a true knowledge of the hinge, as is shown by Dall's statement (1903, p. 1283) that it had three cardinal teeth. Woods (1907, p. 165) has since clearly shown by his description and figures of the genotype that the cardinal teeth are on the Cardiid pattern, even to the cycloid arrangement.

The *Lahillia* hinge is so like the Cardiid one (lacking only the anterior lateral tooth) that relationship is certainly closer to the Cardiidae than to any other family that has yet been proposed. Whether *Lahillia* should remain in the Cardiidae or not is merely a question of how comprehensive a family should be. The sub-family Lahilliinae was proposed so as to draw attention to the differences from the Cardiidae and at the same time not lose sight of the affinities to it. The same effect is got by recognising the family Lahilliidae as a member of the super-family Cardiacea. Although Cardiids are so numerous, and so varied in many of their characters, their hinges are very conservative. Consequently the complete absence of an anterior lateral in *Lahillia* may be taken as of greater importance than usual for such a character. This, together with the tendency to sinuation in the pallial line, and the lack of sculpture or of radial structure in the shell (including absence of marginal crenulations) induces the writer, following Frizzel's (1936) treatment of the Veneridae, to elevate the Lahilliinae to family

The Cardiids of New Zealand fall into six distinct groups, easily distinguished, and without intergrading or intermediate members.

Key to Genera and Subgenera.

A. Small, generally well under 1 inch diameter.
- a. Sculpture of fine radials, posterior area well differentiated .... *(Pratulum)*
- b. Sculpture of coarse radials, interior with radial rows of pits .... *Ethmocardium*

B. Large, over 2 inch diameter.
- a. Sculpture of posterior area not differentiated, whole surface strongly ribbed
  1. Longitudinally oval; ribs tuberculate, especially antero-ventrally. .... *Maoricardium*
  2. High oval; ribs not tuberculate .... *(Oricardium)*
- b. Sculpture of posterior area strongly differentiated.
  1. Almost smooth medially, concentrically waved antero-ventrally, posterior area finely radially ridged .... *Varicardium*
  2. Strongly ridged by smooth rounded ribs, those on posterior area lower and bevelled with linear interstices .... *Hedecardium*

The following table shows the current classification of the species, also the revised classification:—

Current Classification.	Revised Classification.
Cardium brunneri Hector	*Hedecardium brunneri* (Hector)
coxi Hector	indeterminable, probably distorted *Maoricardium*
facetum Suter	*Venericardia* sp. indet.
gudexi Laws	*Maoricardium gudexi* (Laws)
oneroaensis Powell	*Maoricardium oneroaense* (Pow.)
spatiosum Hutton	*Maoricardium spatiosum* (Hutt.)
strangi Laws	*Maoricardium strangi* (Laws)
subcordatum Suter	*Hedecardium subcordatum* (Suter)
Cardium (Trachycardium)	
cantuariense Laws	*Hedecardium cantuariense* (Laws)
greyi (Hutton)	*Hedecardium greyi* (Hutt.)
waitakiense Suter	*Hedecardium waitakiense* (Suter)
Cardium (Fragum)	
dolichum Suter	*Procardia dolicha* (Suter)
maorinum Suter	*Procardia dolicha* (Suter)
priscum Suter	*Hedecardium brunneri* (Hector)
Cardium sp. 1, Woods	*Cardium* sp.
Cardium sp. 2, Woods	*Ethmocardium woodsi* n.sp.
Nemocardium	
alatum Suter	*Varicardium patulum* (Hutt.)
patulum (Hutton)	*Varicardium patulum* (Hutt.)
serum (Hutton)	*Varicardium serum* (Hutt.)
Nemocardium (Pratulum)	
diversum Marwick	*Nemocardium (Pratulum) diversum* Marw.
finlayi Bartrum and Powell	*Nemocardium (Pratulum) finlayi* Bart. and Pow.
pulchellum (Gray)	*Nemocardium (Pratulum) pulchellum* (Gray)
semitectum Marwick	*Nemocardium (Pratulum) semitectum* Marw.

As will be seen from the list, the shells that have generally been classed under *Cardium* s. str. are those of the *Cardium spatiosum* group for which the new genus *Maoricardium* is proposed. They are huge, thick, veneriform shells with strong, tuberculate ribs, related to the Boreal *Cerastoderma* and *Clinocardium*. They are first known from the Duntroonian (Upper Oligocene).

Trachycardium was introduced into New Zealand systematics, on Dall's advice, by Suter (1907) when he described *C. waitakiense* and the usage has been fairly consistently maintained by subsequent workers. The shells, however, though having the right cardinals cemented together, are very distant from *isocardia L.*, the type of *Trachycardium*, both in shape and sculpture, particularly in the differentiation of the posterior area; consequently the new genus *Hedecardium* has been set up. The line is rather commonly represented in New Zealand from the Bortonian (middle Eocene) to the Awamoan (lower Miocene) and the type of sculpture appears to be unique. The group is probably endemic and may have descended from an Upper Cretaceous ancestor which has not yet been discovered. Of overseas species, the Patagonian *C. philippii* shows some resemblance. It has similar, strong, smooth radials, but the anterior ones are differentiated and the posterior ones slightly tuberculate in a different manner. The Victorian *C. pseudomagnum* McCoy may also be related.

Much closer relatives to the *Trachycardium* stock, however, are present in the New Zealand Tertiary. *Ovicardium* certainly has similar shape and type of ribbing and must have a common origin with *Trachycardium* and the Australian *Regozara*. *Trachycardium senu lato* is very widely and strongly represented in the Indo Pacific region.

Two quite distinct groups were classed by Suter under *Nemocardium* (as a subgenus of *Protocardia*); first, the small, thin, Recent and Pliocene *pulchellum*, since classed in *Pratulum* Iredale, and second, the much larger species such as *alata* and *sera*. Stewart (1930, p. 274) has discussed the *Protocardia-Nemocardium-Pratulum* groups and given good reasons for generically separating *Nemocardium* from *Protocardia*, but he left the relationship of *Pratulum* to *Nemocardium* an open question.

The *Pratulum* line has had a long history in New Zealand, evidence for continuity since the Wangaloan (Danian) being very good. The pre-Pliocene shells do not have the transverse sculpture, including tubercles on the posterior ribs, so well developed as in the Pliocene and Recent *pulchellum* or the Recent Australian genotype *thetidis* Hedley. The Chatham Island Tertiary *diversum* is, perhaps, closer to *Nemocardium* than to *Pratulum*, for it has the main part of the disc almost smooth, though it lacks tubercles on the posterior ribs. It is, in fact, difficult to decide which of the two groups should be used for several of the species. The Japanese Pliocene and Recent *modestum* Adams and Reeve, for instance, has the radials of the disc better defined than those of *diversum*, and no posterior tubercles, yet geographically it would be considered a *Nemocardium*, which has been recorded from the China Sea in *N. bechei* (Ad. and Rve.). In

view of their very close resemblance it seems advisable to retain *Pratulum* as a subgenus of *Nemocardium*.

For the group of large shells classed by Suter in *Nemocardium*, the new genus *Varicardium* is now proposed. The strong, concentric ridges developed antero-ventrally may be an archaic feature, but they are much stronger, yet more irregular, than the concentrics of the Cretaceous *Protocardia*. Only three species are known, and all records of these are from mid-Tertiary beds, Upper Oligocene to mid-Miocene. No close relatives are known from outside New Zealand, so, like *Maoricardium* and *Hedecardium*, the genus is probably endemic and its absence from the lower Tertiary due to the imperfect record.

Suter's use of *Fragum* cannot be defended. One of the species, *priscum*, is based on a distorted internal cast probably a *Hedecardium*. The other two species are based on much distorted largely decorticated casts here identified as *Procardia* Meek.

RANGES OF GENERA AND SPECIES.

	Upper Cretaceous		Eocene			Oligocene				Miocene					Pliocene				
	Piripauan	Danian		Bortonian	Tahuian	Kaiatan	Whaingaroan	Duntroonian	Waitakian	Hutchinsonian	Awamoan		Tongaporutuan	Urenuian	Opoitian	Waitotaran	Nukumaruan	Castlecliffian	Recent
"Cardium" sp. 1 Woods ..	—																		
Ethmocardium woodsi ..	—																		
Hedecardium brunneri ..				—	—	—													
„ *waitakiense* ..							—	—											
„ *olssoni* ..								—											
„ *subcordatum* ..								?											
„ *greyi* ..									—	—	—	—							
„ *cantuariense* ..											—								
Maoricardium strangi ..								—											
„ *gudexi* ..											—								
„ *oneroaense* ..												—							
„ *spatiosum* ..													?	?	—	—	—		
Nemocardium ..																			
(*Pratulum*) *modicum* ..		—																	
„ *semitectum* ..						—													
„ *diversum* ..				?															
„ *quinarium* ..															—				
„ *finlayi* ..															—	—			
„ *pulchellum* ..																—	—	—	—
Varicardium serum ..								?			?								
„ *patulum* ..											—	—							
Trachycardium ..																			
(*Ovicardium*) *rossi* ..															—	—			
„ *parki* ..																		—	

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TYPES.

The holotypes of new species described below are in the collection of the New Zealand Geological Survey.

2. SYSTEMATICS.

CARDIIDAE.

Genus ETHMOCARDIUM White.

1880. *Proc. U.S. Nat. Mus.* 2: 292.

Genotype (o.d.): *Cardium whitei* Dall. Upper Cret., Colorado and Montana. Figured (as *speciosum* M. & H.) by Meek, U.S.G.S. Territ., vol. ix, Pl. 37, Figs. 4, a, b, c.

Ethmocardium woodsi n.sp. (Plate 36, Fig. 21.)

1917. *Cardium* sp. 2. Woods, *N.Z. Geol. Surv. Pal. Bull.* 4: 33, Pl. 18, Figs. 4, 5.

The tubercles that Woods drew attention to and figured are a diagnostic feature. They are cylindrical, flat-topped projections of the matrix on the surface of the internal cast and represent small pits arranged in radial rows on the interior of the shell within the pallial line. They are not the internal reflections of tubercles, on the main radials at all events, because the rows are opposite the rib interstices of the exterior. On the holotype the pits are absent from much of the anterior part of the disc, but on the paratype (Woods, Fig. 4) there are three additional rows anteriorly.

Dall (1900, pp. 1071, 1072, footnote) has discussed a similar condition that characterises the genus *Ethmocardium*, based on the West American, Upper Cretaceous *Cardium whitei* Dall and represented in the Turonian of north-west France by *C. alternata* d'Orb. A further species, *E. welleri* Stephenson (1941, p. 195), has been described from the Navarro (Maestrichtian) of Texas.

Woods did not consider the New Zealand material worth naming, but the restricted generic identification that is here made alters the position, so the specific name *woodsi* is proposed. There are only about 25 radial ribs, which are consequently much broader than those of either of the American species.

The hinge of *Ethmocardium* does not seem to have been observed.

Height, 12 mm.; length, 12 mm.; inflation (1 valve), 4 mm.

Locality: G.S. 589. Selwyn Rapids. Piripauan, Upper Cretaceous.

Cardium sp. 1, Woods.

1917. *N.Z.G.S. Pal. Bull.* 4: 33, Pl. 18, Figs. 3a, b.

Locality: G.S. 13. Calcareous conglomerate, Amuri Bluff, Piripauan.

Only the single cast figured by Woods is known. Although the umbo appears to be opisthogyrous, the hinge, as far as can be deter-

mined, is on a Cardiid pattern. It well may be that the internal cast does not show the true twist of the umbones. Retention under *Cardium sensu lato* seems to be the best course for the present.

Cardiidae.

Genus Hedecardium nov.

Shell moderate to very large, subcircular, subequilateral to oblique, inflated, in substance relatively thin. Lunule lanceolate, smooth, raised on hinge margin over cardinals. Escutcheon on large species. Sculpture of numerous, strong, generally smooth, radial ribs, with well defined, generally narrower interstices, the ribs semicircular to subquadangular in cross section, interstices with close, waved, concentric ridges. Posterior area sharply differentiated, radials low, bevelled, with linear interstices that in youth bear small denticles. Hinge-line narrow, right cardinals welded together full length, posterior one long, slender, upcurved; anterior one short, bluntly conic; left hinge with anterior cardinal long, slender, pointed; posterior short, blunt, situated considerably higher on the hinge; laterals of moderate size, rather narrow, sharply pointed. Muscle impressions relatively small, pallial line broad, bluntly angled postero-ventrally thence ascending almost vertically and somewhat sinuously, distant from posterior margin, to meet posterior adductor at its antero-ventral corner.

Genotype: *Cardium waitakiense* Suter, Oligocene.

This line persisted in New Zealand from Bortonian (mid-Eocene) to a little later than Awamoan (low-Miocene) and produced shells as large as 140 x 150 mm. In general shape, *Hedecardium* is like *Vepricardium* Iredale; but the sculpture is different, the posterior area much more differentiated, the adductor scars considerably smaller and the posterior part of the pallial line set further in from the margin.

The later species, *greyi* and *cantuariense*, besides being larger than the earlier species have a wide posterior gape. This raises the question whether they are really of the same lineage as *Hedecardium s.str.* It is possible that they represent an invasion of a related but distinct stock. However, since all other characters agree closely, it seems best to regard the gape as having developed from *waitakiense*.

The Victorian Miocene *C. pseudomagnum* McCoy is not unlike some of the later, large species of *Hedecardium;* but it is not clear whether the posterior area is similar. According to McCoy *pseudomagnum* is not close to any other Australian species.

Few changes are seen in the characters of the group throughout its known range. There is a progressive increase in size and some tendency towards flattening and widening of the ribs. The posterior area is quite different in appearance because its ribs differ from those on the rest of the shell. For convenience of description the ribs are here termed "posterior" and "main." The main ribs can be divided again into "anterior" and "medial." The anterior ones are more rounded and have wider interstices than the medial, but there is no sharp division.

KEY TO SPECIES OF *Hedecardium*.

A. Adult under 75 mm. long, posterior margin closed.
  (I) Medial ribs equal to or narrower than interstices.
    (a) Adult under 40 mm. long .... *brunneri*
    (b) Adult over 50 mm. long
      (1) Main ribs numbering 40–47 .. . . *waitakiense*
      (2) Main ribs numbering 37 . . .. *olssoni*
  (II) Medial ribs much broader than interstices ... *subcordatum*
B. Adult over 75 mm. long, posterior margin gaping.
  (1) Medial ribs about equal to interstices ... . *greyi*
  (2) Medial ribs much broader than interstices .... *cantuariense*

Hedecardium brunneri (Hector). (Plate 36, Figs. 9, 11.)

1886. *Cardium brunneri* Hector, *Outline N.Z. Geol.* p. 58, f. 20, no. 5.
1915. Suter, Alph. Handlist: 6.
1917. *Cardium* (*Fragum*) *priscum* Suter, *N.Z.G.S. Pal. Bull.* 5, p. 77, pl. 10, fig. 6.

Shell somewhat small, subcircular, beaks fairly prominent, moderately inflated. Sculpture of about 40 strong, rounded, main radial ribs with deep interstices of about the same width; posterior area probably with about 12 flat ribs with linear interstices.

Height, 30 mm.; length, 34 mm.; inflation (1 valve) 11 mm.

The shell is somewhat distorted. originally it was more nearly circular.

Localities: G.S. 29, Island Sandstone, Brunnerton (type). G.S. 45, Sandstone below limestone, St. Kilda, Brighton, West Coast. G.S. 1593, Millerton Colliery, West Coast, 150 feet above coal, Kaiata Mudstone. G.S. 27, Ten Mile, Greymouth, Island Sandstone. Near Kiwi Compressor, Denniston Colliery, West Coast, Kaiata Mudstone. G.S. 578, Greensand below limestone, Kakahu River. G.S. 480, Concretionary sandstone below greensand Waihao River. G.S. 176, Sandstone above coal beds, Black Point, North Otago. G.S. 2119, Concretions in silts, Green Valley, Waihemo S.D. G.S. 41, "Black Limestone, Tokomairiro," Otago.

This species, frequently mentioned in the early discussions of West Coast stratigraphy, has not previously been described, its only claim to legality being a crude figure and a good locality. These are quite sufficient for recognition, within somewhat wide limits, but better specimens from the type locality may, some day, be found. A specimen from G.S. 29, Brunner Mine, from beds overlying the coal has been chosen as lectotype (Pl. 36, Fig. 9). It is accompanied by an old Colonial Museum label and presumably was identified as *C. brunneri* by Hector; it probably represents original syntype material.

Hedecardium waitakiense (Suter). (Pl. 35, Figs. 1, 2, 5.)

1907. *Cardium* (*Trachycardium*) *waitakiense* Suter, *Proc. Mal. Soc.*, vol. vii, p. 209, pl. 18, fig. 6.
1915. Suter. *N.Z.G.S. Pal. Bull.* 3, p. 59, pl. 8, fig. 20.

Suter described this species from the fragment of a right hinge. A complete specimen of each valve as well as a number of hinge fragments were collected by the writer from the type locality, so that Suter's description can now be amplified. The ribs number about 40; they are flattened on top and separated by regularly rounded interspaces. On about juvenile half of shell medial ribs are wider

than interspaces, but on adult, interspaces are wider than ribs; flattened tops of main ribs are smooth and glossy, but interspaces bear close, fairly regular but somewhat undulating concentric growth-ridges. Posterior, which is glossy throughout, bears about 14 of the peculiarly differentiated, flattish ribs. In juvenile these ribs are not raised and several of the anterior ones bear a shallow longitudinal furrow; they are separated by linear grooves set with small tubercles which are really developed on anterior side of each rib. In adult, ribs become raised, at first strongly bevelled, steep face anterior, but finally more rounded, and there are no tubercles.

Localities: " Greensand, Wharekuri " (type); G.S. 476, *Kekenodon* Beds, Wharekuri; G.S. 1821, north bank, Waitaki River, opposite Wharekuri; G.S. 1913, Shell Gully, Kelly's farm, Chatton; G.S. 2108, Greensand, Te Raumaku School, 2½ miles west of Otorohanga; G.S. 526, 1027, Okoke, Pirongia S.D. (Duntroonian).

Hedecardium olssoni, n.sp. (Pl. 35, Fig. 6; Pl. 37, Fig. 25)

Shell of moderate size, like *waitakiense* but differing in having only 37 instead of from 40–47 ribs. Main ribs noticeably higher and broader than those of *waitakiense*, but relationship of rib to interstice on different parts of disc about the same Shell shape also differs, posterior end being more truncate and whole shell more stoutly built.

Height, 61·5 mm.; length, 62 mm.; inflation, 23 mm..

Locality: G.S. 1913, Shell Gully, Kelly's Farm, Chatton (Duntroonian)

Although this shell is of the same age as *waitakiense,* the fewer triangular ribs and wide interstices justify separation. The number of ribs is much the same as that of *subcordatum*, but the wide interspaces between the sharply ridged ribs characterise olssoni. The species is named in honour of Mr Axel A. Olsson, of Gloversville, New York, with whom the writer spent a most pleasant collecting trip.

Hedecardium subcordatum (Suter).

1917. *Cardium subcordatum* Suter, *N.Z.G.S. Pal. Bull.* 5, p. 77, pl. 10, fig. 7.

Only the holotype of this species is known. It has about 37 main ribs and 12 posterior ones. The main ribs have flattened tops and are about twice as wide as the interstices.

Locality: Suter gave in his original description " Shell-bed at base of ' Pareora ' beds, junction of Porter and Thomas Rivers, Trelissick Basin " and the accompanying label says " Trelissick Basin B." (See Pal. Bull. 8, p. 50.) A good deal of matrix adheres to the specimen and since it is tuffaceous, the locality is wrong. The tuff consists of greenish grey much weathered volcanic fragments set in a good deal of secondary calcite, and is the same in appearance as the tuffs between limestones at the junction of the Porter and Thomas Rivers. Also adhering to the holotype, and shown in the original photo, is a specimen of *Modiolaria elongata* (Hutton), a species occurring commonly at this locality and not in the shell bed overlying the upper limestone. It is quite clear then that the true locality is " Tuffs between limestones, junction of Porter and Thomas Rivers." The faunules of this bed, both Foraminiferal

(H. J. F.) and Molluscan are of unusual facies, so correlation is not obvious, but probabilities indicate Duntroonian.

Hedecardium greyi (Hutton). (Pl. 35, Fig. 4.)

1873. *Cardium greyi* Hutt. *Cat. Tert. Moll.*, p. 23.
1915. Suter, *N.Z.G.S. Pal. Bull.* 3, p. 59, pl. 1, fig. 3.
1929. *C. (Trachycardium) greyi* Pow. & Bart., *Trans. N.Z. Inst.*, vol. lx, p. 408, figs, 35, 36, 39, 40.

It is doubtful whether *cantuariense* can be maintained as a distinct species from *greyi*. Probably the question can be definitely settled only by statistical methods which must wait on the accumulation of numbers of specimens. Members of the group occur at a number of localities from the Waitakian to somewhat above the Awamoan. They are very large shells, some exceptionally large, differing from the earlier species of *Hedecardium* not only in greater size and shell-thickness, but also in having a pronounced posterior gape. As shown by the growth lines, this gape develops at an early stage, well before half the adult diameter is reached.

Kyeburn shells have fairly well-rounded ribs throughout, as also do the fragments from Otiake. Law's figures of *cantuariense* on the other hand, show considerable flattening of the adult medial ribs, accompanied by a relative narrowing of the interstices. A fine left valve from Ardgowan has flattened ribs like *cantuariense*, but it is smaller (79 x 80 x 35 mm.) yet is more inflated and regularly globose than usual for members of the group which generally become oblique with maturity. Oneroa shells seem to be somewhat variable in medial rib-width as also are the Mangapakeha ones which, incidentally, measure up to 145 x 150 x 60 mm. The Mokau and Clifden shells seen are poorly preserved, but in general their medial ribs tend to be flattened. From this it appears that flattening of the medial ribs and relative narrowing of the interstices may perhaps be used to separate stratigraphic species.

Hedecardium cantuariense (Laws). (Pl. 35, Fig. 3.)

For remarks see previous species.

Locality: Sutherlands, South Canterbury (type); G.S. 1985, shell bed, Ardgowan, North Otago.

Genus MAORICARDIUM nov.

Shell very large, thick, umbos strongly prosogyrous, at anterior third or fourth. Lunule with raised margin; escutcheon not defined. Sculpture of numerous strong radials bearing blunt, cup-shaped tubercles, especially anteriorly and ventrally. Hinge long, moderately wide cardinals; left anterior cardinal short conical, left posterior cardinal long, not so high, almost horizontal, close to ligamental nymph; left anterior lateral high and strong, without socket for right anterior; left posterior lateral, weak; right posterior cardinal very large, right anterior also relatively large; laterals strong. Ligamental nymphs long and very high.

Genotype: *Cardium spatiosum* Hutton. Pliocene.

This lineage of Cardiidae was relatively common in New Zealand in the middle and later Tertiary. Four species have been described, *C. strangi* Laws, Duntroonian (Oligocene), *C. gudexi* Laws, *C. oneroaense* Pow. (Miocene), and *C. spatiosum* Hutton (Lower Pliocene). The shells, especially of *C. spatiosum* grew to a

great size, a length of 150 mm. being not uncommon. No close relatives of the group appear to be known in Australia or South America, the nearest being the North Pacific *Clinocardium* Keen and the North Atlantic *Cerastoderma* (Poli) Moerch. *Maoricardium* differs from *Clinocardium* in its high ligamental nymph and in the strong, cup-shaped tubercles on the ribs. From *Cerastoderma* it differs in its much greater size, larger right cardinals, and almost horizontal left posterior cardinal which, besides, is close to the nymph. The left posterior cardinal is weaker and nearer the dorsal margin.

KEY TO SPECIES OF *Maoricardium*.

A. Ribs, about 50, lightly built, shape elongate subquadrate. *strangi*
B. Ribs, about 38, heavily built.
  I. Rib interstices narrow to linear, shape subquadrate. *gudexi*
  II. Rib interstices broad, shape elongate subquadrate ...... *spatiosum*
C. Ribs, about 41 .... *oneroaense*

Maoricardium strangi (Laws).

1930. *Cardium strangi* Laws, *Trans. N.Z. Inst.*, 61: 549, figs. 6, 9.

Locality: Shell Gully, Kelly's Farm, Chatton.

Age: Duntroonian.

A second specimen, a left valve, now in the Geological Survey Collection, has been collected at the type locality by Mr Axel A. Olssen, Mr E. O. Macpherson, and the writer. This specimen is somewhat more attenuated than the holotype.

Maoricardium gudexi (Laws). (Pl. 37, Fig. 29.)

1933. *Cardium gudexi* Laws, *Trans. N.Z. Inst.*, 63: 316, figs. 7, 14.

Localities: Sutherlands, South Canterbury (type); shell bed above upper limestone, lower gorge of Porter River, Trelissick Basin.

The Trelissick specimen has well developed tubercles like *oneroaense*, but the radials are flat. See remarks under *oneroaense*.

Maoricardium oneroaense (Powell).

1938. *Cardium oneroaense* Pow., *T.R.S.N.Z.*, 68: 367, pl. 38, figs. 7-8.

The type of *oneroaense* has a few more ribs than the type of *gudexi*, and they are slightly more convex, the anterior tubercles are better developed, also the shell is lighter built, so that the hinge is less arched. These differences are little, if any, greater than those to be seen between individuals of *M. spatiosum*, and since the matrix of *oneroaense* is more argillaceous than that of *gudexi*, the differences may be due to habitat. As in the case of *H. greyi* and *cantuariense*, the true relationship of these forms can only be determined from a larger number of specimens than now available.

Locality: Oneroa, Waiheke Island.

Age: About Awamoan.

Maoricardium spatiosum (Hutton). (Pl. 37, Fig. 30.)

1873. *Cardium spatiosum* Hutt., *Cat. Tert. Moll.* 23.
1914. Suter, *Pal. Bull.* 2: 52, pl. 15, figs. 1a, b.

Localities: Waitotara (type) the precise locality has not been determined: *M. spatiosum* occurs widely in Waitotaran beds and was obtained by Laws (1940, p. 37) from beds considered to be low in the Nukumaruan. This appears to be an exceptional occurrence, however, for the species is not known from the Nukumaruan elsewhere. *Maoricardium* is known from Opoitian and Taranakian beds

at several places and has generally been recorded as *spatiosum.* No good specimens, however, have yet been seen from beds between Awamoan and Waitotaran, so where the boundary should be drawn between *spatiosum* and *gudexi* is not known.

Genus NEMOCARDIUM Meek.

1876. *Dep. Inter. Rep. U.S. Geol. Surv. Terr.*, vol. ix, p. 167.
Genotype (monotypy): *Cardium semiasperum* Desh. Eocene, Paris Basin.

Subgenus PRATULUM Iredale.

1924. *Proc. Linn. Soc. N.S.W.*, vol. xlix, p. 182.
Type (o.d.): *Cardium thetidis* Hedley. Recent, N.S. Wales.

The use of *Nemocardium* and its relation to *Pratulum* are discussed in the introduction to this paper.

KEY TO SPECIES OF *(Pratulum).*

A. Main ribs weakly developed.
- (a) Surface almost smooth, main ribs indicated by weakly incised lines. .... *diversum*
- (b) Ribs plainly defined, but very low .... *modicum*

B. Main ribs well developed.
- (I) Medial ribs at 10 mm. from umbo 5 per mm.
  - (a) Interstices narrow. .... *semitectum*
  - (b) Interstices wide. .... *quinarium*
- (II) Medial ribs at 10 mm. from umbo 3 per mm. ...... *pulchellum*
- (III) Medial ribs at 10 mm. from umbo 2 per mm. ...... *finlayi*

Nemocardium (Pratulum) modicum n.sp. (Pl. 36, Figs. 17, 18.)

1937. *Nemocardium (Pratulum)* sp. Finlay and Marwick, *N.Z.G.S. Pal. Bull.* 15, p. 30, pl. 4, fig. 6.

Shell small. Main ribs, about 45, scarcely raised, broadly rounded, separated by linear interstices and crossed by numerous growth lines. Posterior ribs, about 16, very narrow, irregularly, weakly nodular, separated by wide, flat interstices, growth lines strongly marked.

Height, 6·5 mm.; length, 7 mm.; inflation, 2·6 mm.

Localities: Boulder Hill, near Dunedin, type; Wangaloa (Danian).

The sculpture though preserved on only a small part of the holotype is clearly enough shown to enable easy differentiation from other species. Consequently reconsideration of the type material seems to justify granting a name.

Nemocardium (Pratulum) semitectum Marwick.

1926. *Nemocardium semitectum* Marw., *Trans. N.Z. Inst.*, vol. lvi, p. 312, pl. 72, fig. 8.

In the original description the statement about the ribbing needs correction. The diameter 22 mm. should read 12 mm., and the number of ribs should be 5 for medial ribs and 6 for anterior.

Locality: Tuffs, Lorne (Lower Kaiatan-Waiarekan).

Nemocardium (Pratulum) diversum Marwick.

1928. *Nemocardium diversum* Marw., *Trans. N.Z. Inst.*, vol lviii, p. 472, fig. 85.

Locality: Tuffs, Waikaripi, Chatham Island.

The age of this species is not known, but the general affinities of the faunule accompanying it are with Eocene and Oligocene species in New Zealand.

Nemocardium (Pratulum) quinarium n.sp. (Pl. 36, Figs. 10, 16.)

Shell small. Radial ribs rounded, very fine, medials 5 per mm. at 10 mm. from umbo; main ribs, about 70; interstices well marked, nearly as wide as ribs; concentric ridges well developed, closely placed. Posterior ribs, 32; narrow and high rounded, not tuberculate, connected across wide interspaces by strong transverse ridges, not crossing radials and not corresponding in adjacent interstices.

Height, 11 mm.; length, 12 mm.; inflation, 4 mm.

Localities: G.S. 1325, roadside just east of Mangatarehu Stream, Waikohu Surv. Dist. (type); G.S. 1369, 36 chains north-west of Trig. A, Waingaromia Surv. Dist.; also many other localities in Gisborne district. (Opoitian.) Many examples also in Opoitian beds in Wairoa Subdivision.

N. quinarium can be distinguished from *pulchellum* not only by the finer and more numerous ribs but also by the narrow interstices and the well developed transverse bars and absence of tubercles on the posterior area.

Nemocardium (Pratulum) finlayi Bartrum and Powell.

1928. *Nemocardium finlayi* Bart. & Pow., *Trans. N.Z. Inst.*, vol. lix, p. 159, fig. 48.

Localities: Kaawa (type), (Opoitian); G.S., 1560, Waihua River, Hawke's Bay (? low Waitotaran).

Nemocardium (Pratulum) pulchellum (Gray). (Pl. 36, Figs. 12, 13, 20.)

1843. *Cardium pulchellum* Gray, Dieffenbach's N.Z., p. 252.

1913. *Protocardia (Nemocardium) pulchella* (Gray): Suter, Manual, p. 1000, pl. 62, fig. 9.

Localities: Recent, New Zealand, 10–120 faths. Numerous localities in Castlecliffian, Nukumaruan and Waitotaran beds. The species has been recorded from many localities in the Tutamoe Series (Marwick, 1931, p. 77), These should not have been identified so positively as many are no more than generic identifications based on poor material. None are from the typical Tutamoe beds of Muddy Creek, but all are from the upper part of the series as then used, and are probably Taranakian and higher. *N. pulchellum* does not seem to go below the Waitotaran.

Genus Varicardium nov.

Shell fairly large, subcircular to suboval, subequilateral. Lunule with raised inner margin; escutcheon narrow, deep. Sculpture: Middle of disc, when well preserved, smooth and glossy, but with very fine, concentric lines, also almost equally fine radials defined by subsurface or very shallow lines; anterior and ventral part of disc with strong, concentric, undulating, rounded, bevelled ridges; posterior area with numerous strong, smooth, close, radial ridges. Hinge moderate to strong, laterals well developed; right valve with strong, vertical, hooked, posterior cardinal, connected to half its height with anterior, transverse cardinal which is a scarcely raised pad on thick lunular margin; left hinge with strong, vertical, anterior cardinal and very weak, oblique, curved, posterior cardinal. Valve margins dentate, those of posterior coarser.

Genotype: *Varicardium patulum* Hutton, Miocene.

Varicardium differs from *Nemocardium* in having strong concentric ridges anteriorly and ventrally, and in consistently lacking

tubercles on the posterior area. Also *Varicardium* is typically much larger and heavier built, though the Paris Basin Eocene *N. wateleti* (Desh.) is about as large as *N. serum*. The group is first known from about Duntroonian; it occurs fairly widely about the Awamoan and somewhat later, but it has not been found in the Taranakian.

KEY TO SPECIES OF *Varicardium*.

A. Subcircular; length, about 80 mm.; moderate hinge. ...... *patulum*
B. High Oval. Rather lightly built, under 60 mm. long. Restrained hinge, concentric ridges, about 1½ mm. apart. *serum*

Varicardium serum (Hutton). (Pl. 37, Figs. 26, 27.)

1873. *Protocardium serum* Hutt., *Cat. Tert. Moll.*, p. 23.
1886. *Protocardium serum* Hector, *Outline N.Z. Geol.*, p. 54, fig. 15, no. 13.
1914. *Protocardia* sera Hutt., Suter, *N.Z.G.S. Pal. Bull.* 2, p. 53, pl. 14, fig. 8.
1926. *Nemocardium patulum* (Hutt.), Finlay, *T.N.Z.I.*, vol. lvii, p. 471.

As will be seen from the discussion under the following species, *V. serum* should not be synonymized with *patulum*, the type locality of which must be regarded as The Deans, Waipara, and from which it can be readily separated by its higher, less circular outline. The rather crude figures of Hector's Outline give a very good rendering of this difference in shape.

Localities: As shown by the peculiar matrix, Hutton's Broken River locality of his 1873 Catalogue, in most cases, is really the same as Geol. Surv. 239 (and some of 449), " Tuffs between limestones, Junction of Porter and Thomas Rivers, Trelissick Basin." (Perhaps Duntroonian.) G.S. 2946, Clifden, zone 6a (about Awamoan).

Varicardium patulum (Hutton). (Plate 37, Figs. 24, 28, 32, 33.)

1873. *Cardium patulum* Hutt., *Cat. Tert. Moll.*, p. 23.
1886. *Cardium patulum* Hutt., Hector, *Outline N.Z. Geol.*, p. 54, fig. 15, no. 3.
1917. *Protocardia (Nemocardium) alata* Suter, *N.Z.G.S. Pal. Bull.* 5, p. 78, pl. 10, fig. 8.
1924. *Protocardia patula* (Hutt), Finlay, *T.N.Z.I.*, 55, p. 498, ? includes *sera* and *alata*.
1926. *Nemocardium patulum* (Hutt), Finlay, *T.N.Z.I.* 57, p. 471.

When Suter (1914) revised Hutton's 1873 types, several were missing. Most of these have since been found, and among them that of *Cardium patulum*. The shell, which is from The Deans, Waipara, is fairly complete and proves to be easily distinguished by shape from *V. serum*. Unaware that Hutton's type had been recovered, Finlay designated Broken River (Lower) as the type locality of *patulum*. Hutton, however, gave as localities, " The Deans, Waipara; Broken River (L) ? ". By analogy with Internat. Rules, Art. 30, sect. IIe, γ, the doubtful locality is not available and the other is automatically the type. This, in addition to the existence of Hutton's original type, invalidates the Broken River designation.

Although Suter's holotype of *alata* is only a fragment, it is clearly conspecific with the type of *patulum*. Both are from the same district, Suter's specimen, collected by Thomson (1920, p. 363) from a shell bed at the base of the Main Mount Brown limestone in Weka Creek, and Hutton's from The Deans, Waipara, some three miles south along a prominent escarpment.

Localities: The Deans, Waipara (type). Lower shell bed below uppermost Mt. Brown limestone, Weka Creek. Glauconitic sandstone below shell bed, Target Gully, Oamaru. (Awamoan.) Clifden, zones 6b, 6c, 7.

Genus TRACHYCARDIUM Moerch.

Genotype: *C. isocardia* L. Recent, West Indies.

Subgenus OVICARDIUM nov.

Shell large, thick, obliquely high oval, closed. Sculpture of numerous square ribs with deep interstices. Lunule slightly concave; no escutcheon. Hinge moderate; left valve with strong anterior cardinal; posterior cardinal very small, almost horizontal, having rather deep, wide groove running from below it obliquely back across hinge. Left anterior lateral (AII) very long and strong, bounded above by a deep groove extending past it towards umbo; ventrally with only weak depression for reception of A I. Posterior lateral rather small, continuing into ligamental groove behind high nymph.

Genotype: *Trachycardium* (*Ovicardium*) *rossi* n.sp.

This shell belongs broadly to the *Trachycardium* group, fairly large, high, oval shells with strong ribs. The following groups fall into this category, and their use as subgenera under *Trachycardium* recognises their differences yet preserves what appears to be an obvious relationship:—

Trachycardium Moerch, 1853; *Phlogocardia* Stewart, 1930; *Mexicardia* Stewart, 1930; *Dallocardia* Stewart, 1930; and *Regozara* Iredale, 1936.

Agnocardia Stewart was also proposed as a subgenus of *Trachycardium* in 1930, but it does not have the oval form characteristic of the groups mentioned, and may not be closely related. *Regozara* is an Australian group, the others all belong to the tropical and sub-tropical seas of America, some eastern, some western. *Ovicardium* might reasonably then, be expected to show closer agreement with *Regozara* than with the American subgenera, but such is by no means obvious. About the only common point of difference from *Trachycardium* s.str. shown by both Austral groups is the larger lateral A II, and even here there is much difference in shape, the general disposition of that of *Regozara* being more like that of *Trachycardium*. Apart from this small hinge difference, *Regozara* differs from *Trachycardium* only in details of sculpture. *Ovicardium*, however, differs from both and also from the other groups in several important features as well as sculpture—namely, (1) the oblique groove across the left hinge; (2) the long, deep groove above A II; (3) the concave lunule. Although we do not yet have a record of it, *Ovicardium* probably has existed as a separate entity since well before the Pliocene.

Trachycardium (Ovicardium) rossi n.sp. (Pl. 35, Figs. 7, 8.)

Sculpture of 51 smooth, strong, radial ribs, in general nearly rectangular in cross-section, with interstices of about equal width. Anteriorly, for about the first 5, the ribs are more rounded, closer and crossed by low, regular spaced ridges. Posterior area not strictly

defined, the more posterior ribs gradually becoming more rounded and lower. The most posterior three much broader.

Height, 102 mm.; length, 95 mm.; inflation (1 valve), 35 mm.

Localities: G.S. 1541, Te Reinga Falls, Hangarua River (type) (Waitotaran); G.S. 1244, Mangatuna Quarry, Uawa Surv. Dist.; Sandstone, Tokomaru Bay. (Opoitian.)

This species is named in honour of Captain D. H. K. Ross, formerly of the Geological Survey, to whom I owe the fine photographs of this fossil.

Trachycardium (Ovicardium) parki n.sp. (Pl. 36, Figs. 19, 22, 23.)

Shell large, high oval, well inflated. Sculpture of 40 squarish main ribs with interstices about half as wide, the rib bounding posterior area of double width; on posterior area are 8 somewhat rounded ribs with shallow interstices, the most posterior two ribs wider than others. Hinge worn but apparently without oblique groove, anterior lateral relatively small.

Height (if complete), 95 mm.; length, 90 mm.; inflation, 35 mm.

Locality: G.S. 634, shell beds, mouth of Butler's (Ototoka) Creek, Nukumaru Surv. Dist. (basal Castlecliffian).

This species is named in honour of Professor James Park, who collected it in 1886. It was listed (Park, 1887, p. 53) as *Cardium multiradiatum* Hutton (rightly of Sowby.).

The single specimen is fragmentary and badly worn, as are many of the shells from this locality. Indeed, some of them have been derived from the erosion of older beds, so that *T. parki* may be older than Castlecliffian.

It is easily distinguished from *T. rossi* by the double rib bounding the posterior area, by the narrower rib-interspaces, by the more narrowly rounded umbo yet more inflated disc, and by the considerably smaller anterior lateral tooth, and lack of a deep socket above it.

SPECIFIC NAMES TO BE DELETED OR SUSPENDED.

Hemicardium cordatum Hector.

1886. *Outline N.Z. Geol.*, p. 56, fig. 19, no. 7.

Locality: Maheno, Oamaru (by a misprint written Mahemo).

The specimen that served as a basis for Hector's figure has not been found, and unless it comes to light, the species cannot be identified even at a guess. Consequently *H. cordatum* must be suspended from our lists. The figure shows a shell having distant beaks bounding a wide area with a ligamental chevron. It thus appears to represent a *Cucullaea* or a *Glycymeris*, certainly not a *Cardium*, which has beaks springing from the dorsal margin. The only Geological Survey collection prior to 1886 localized at Maheno is No. 498, from fine marly beds below the Ototara stone. The specimens are small and thin shelled, quite unlikely to be accompanied by a *Cardium* or a *Cucullaea* 4 inches high.

In Park's collection from this place (1918, p. 44) Suter identified two new species of *Cardium*. Both are distorted casts of *Procardia*.

Cardium coxi Hector.

1886. *Outline Geol. N.Z.*, p. 57, fig. 19a, no. 5.

What is in all probability the original of *Cardium coxi* has now been found in the Geological Survey collections. It bears the locality number 487, which is stated (*Rep. Geol. Explor.* no. 21) to be from Ngapara, North Otago. Part of this collection consists of rusty casts, among them *Monalaria*, and *Hedecardium* cf. *brunneri*, and these probably represent the real Ngapara collection. The other part of collection 487 consists of grey, unoxidised casts, mostly distorted, identical with collection 47, which is from The Castles, Aorere River. This is the locality given by Hector for *C. coxi*.

The specimen is a double valved *Maoricardium* that has been much compressed longitudinally. It has about 40 broad ribs with linear interstices and, antero-ventrally, strong blunt tubercles. Most of the fossils from the locality are too poor to give accurate determinations, but the presence of *Struthiolaria* cf. *prior* Finlay and a large *Hedecardium* cf. *greyi* suggest a Waitakian age. It is impossible to tell from the single specimen whether there are significant differences between it and *strangi* or *oneroaensis*. Of course, if it could be definitely identified with any of these it would take precedence; but, until better material turns up, it seems best to relegate *coxi* to the suspense list.

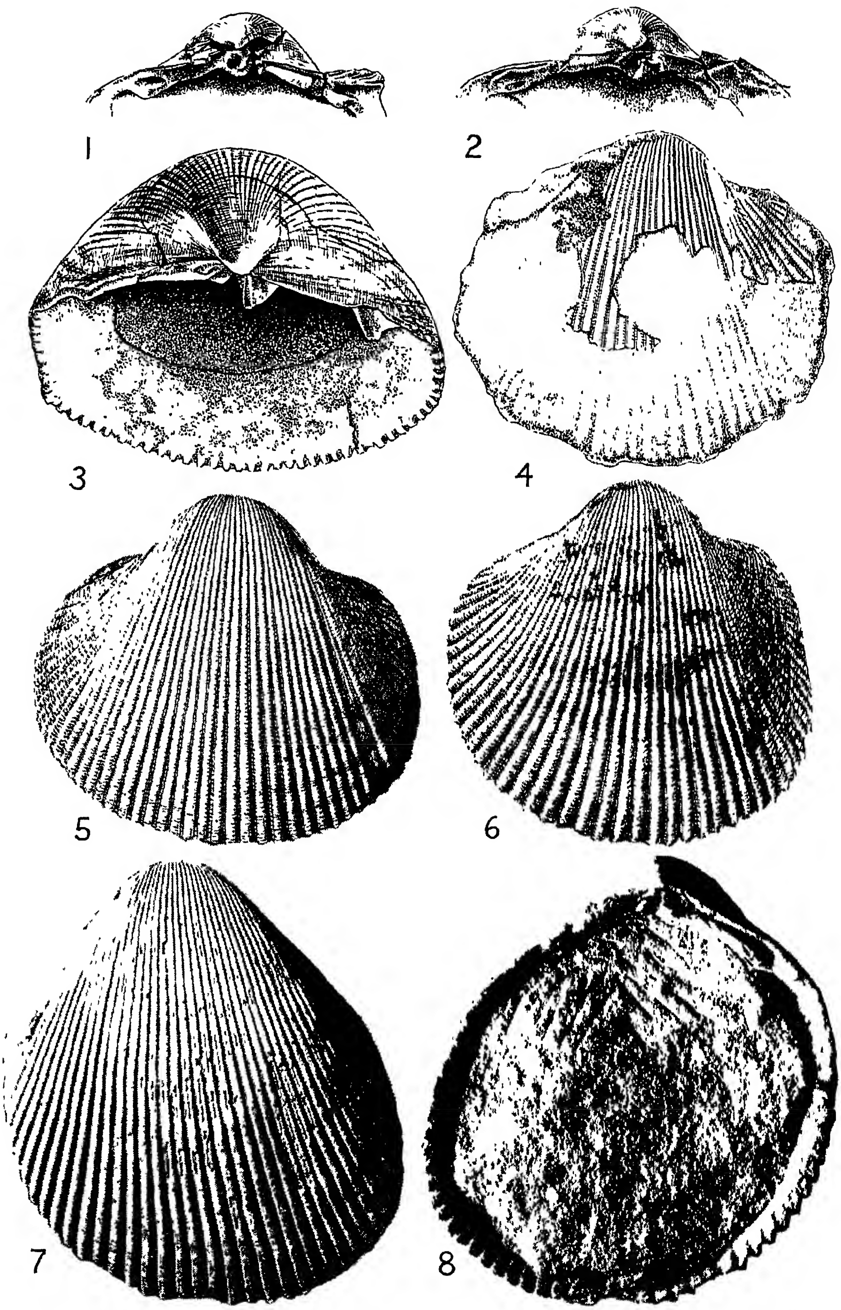
Cardium spatiosum gracile Hector, M.S.

This subspecies was listed by Suter in his *Alphabetical Handlist of N.Z. Tertiary Mollusca,* without any indication of its origin, and again in his *Alphabetical List of N.Z. Tert. Moll.,* 1918, but this time indicating it as a manuscript name. The writer has not been able to find Hector's use of the name, but there is a specimen in Geol. Surv. collection 703, so identified in Suter's writing. It is a decorticated *Venericardia.* In any case there is a prior *Cardium gracile* Pusch, 1836, and one of Muenster, 1837.

Cardium huttoni Ihering.

1907. *Ann. Mus. Nac. Buenos Aires*, vol. xiv, p. 291.

This name was proposed by von Ihering for a Waipara shell that Hutton had identified as the Peruvian *C. multiradiatum* (Sowby.). The shell figured by Suter (1915, pl. 6, fig. 5) as a topotype is a *Hedecardium* and on this basis *huttoni* was synonymized with *greyi* by Powell and Bartrum (1929, p. 408). It is not certain, however, that von Ihering's type specimen is even generically the same as the Canterbury " topotype ". No formal description was given; but a sentence of description and the locality " Miocene of Waipara " can be taken as legalizing the name. The description is: " The first 6–7 anterior radial ribs are furnished with tubercles; the anterior dorsal margin is raised in the middle and crowded against the beak." Now the anterior ribs of *Hedecardium* are not tuberculate, but those of *Maoricardium* are, and *Maoricardium* also occurs at Waipara. Until direct evidence is obtained from von Ihering's type material in the Museum of Sao Paulo, the exact application of *huttoni* must remain in doubt.



D.H.K.R. photo. *K.S.M. del.*

FIGS. 1, 2, 5.—*Hedecardium waitakiense* (Suter). G.S. 1821, Wharekuri, × 0.8.
FIG. 3.—*Hedecardium cantuariense* (Laws). G.S. 1985, Ardgowan, × 0.7.
FIG. 4.—*Hedecardium greyi* (Hutton). Holotype, × 0.8.
FIG. 6.—*Hedecardium olssoni* n.sp. Holotype, × 0.75.
FIGS. 7, 8.—*Trachycardium* (*Ovicardium*) *rossi* n.sp. Holotype, × 0.6.

Facing page 270.

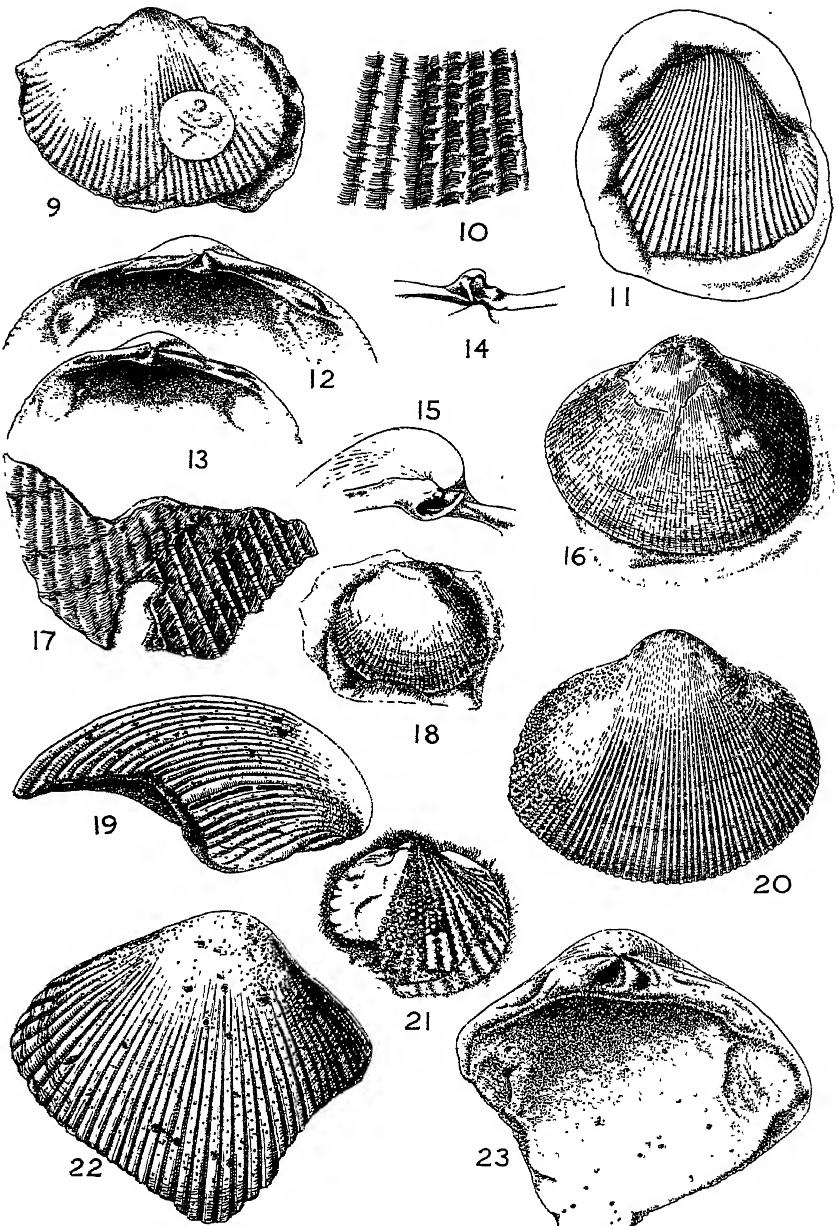


FIG. 9.—*Hedecardium brunneri* (Hector). G.S. 29, Brunner, lectotype, × 1.
FIG. 10.—*Nemocardium* (*Pratulum*) *quinarium* n.sp. Detail of sculpture much enlarged.
FIG. 11.—*Hedecardium brunneri* (Hector). Cast. G.S. 2119, Green Valley, × 1.
FIGS. 12, 13.—*Nemocardium* (*Pratulum*) *pulchellum* (Gray). Seven faths., Tryphena Bay, × 2.
FIGS. 14, 15.—*Hedecardium waitakiense* (Suter). G.S. 1821, showing the cemented right cardinals, 14 from above, 15 from obliquely forward.
FIG. 16.—*Nemocardium* (*Pratulum*) *quinarium* n.sp. Holotype, × 3.
FIGS. 17, 18.—*Nemocardium* (*Pratulum*) *modicum* n.sp. Holotype, × 3. (Sculpture detail much enlarged.)
FIGS. 19, 22, 23.—*Trachycardium* (*Ovicardium*) *parki* n.sp. Holotype, × 0.6.
FIG. 20.—*Nemocardium* (*Pratulum*) *pulchellum* (Gray). Seven faths., Tryphena Bay, × 2.
FIG. 21.—*Ethmocardium woodsi* n.sp. Holotype, × 2. (Note internal pits filled by matrix.)

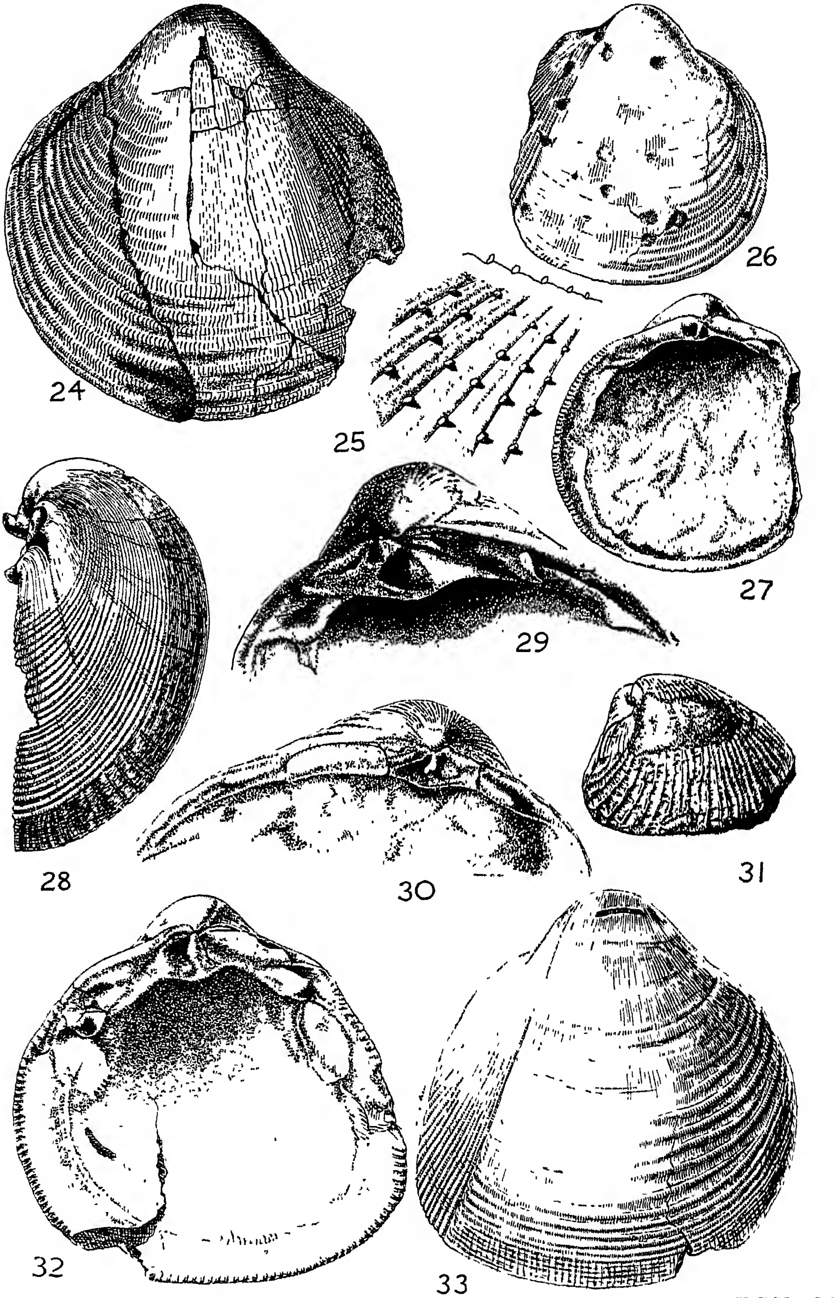


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FIG. 24.—*Varicardium patulum* (Hutton). Holotype, × 0.6.
FIG. 25.—*Hedecardium olssoni* n.sp. Sculpture detail on posterior area of juvenile only, × 9.
FIGS. 26, 27.—*Varicardium serum* (Hutton). Topotype, × 0.6.
FIGS. 28, 32, 33.—*Varicardium patulum* (Hutton). Clifden, zone 7, × 0.7.
FIG. 29.—*Maoricardium gudexi* (Laws). Holotype, × 1. (After Laws.)
FIG. 30.—*Maoricardium spatiosum* (Hutton). G.S. 1101, Waipipi Beach, × 0.7.
FIG. 31.—*Procardia dolicha* (Suter). G.S. 1286, Terakohe, × 0.6.

SPECIES TO BE TRANSFERRED FROM THE CARDIIDAE.

PHOLADOMYIDAE.

Genus PROCARDIA Meek.

1871. *Proc. Acad. Nat. Sci. Phil.*, vol. xiv, p. 184.

Genotype (monotype): *Isocardia hodgii* Meek. Upper Cret. Missouri. Figured, Meek, 1876, *U.S.G.S. Territ.*, vol. ix, pl. 13, figs. 3a, b.

Procardia dolicha (Suter). (Pl. 37, Fig. 31.)

1917. *Cardium (Fragum) dolichum* Suter, *N.Z.G.S. Pal. Bull* 5, p. 76, pl. 9, fig. 4.

1917. *Cardium (Fragum) maorinum* Suter, *N.Z.G.S. Pal. Bull.* 5, p. 77, pl. 13, figs. 7, 8.

These shells generally occur as closed individual with very little of the thin, nacreous shell-material adhering to a much distorted cast. No New Zealand specimens yet found show the hinge. An almost undistorted, double-valved specimen from G.S. loc. 1286, mudstone overlying limestone, Terakohe, is figured below. This shows the characteristic flattened anterior end with its pouting middle zone and large, deeply excavated lunule. The escutcheon is long, rather narrow, slightly concave, and bears no radial ribs. The ligamental nymphs are exposed dorsally and are of moderate length. The radials number about 28, being distally subequal in strength, though some of them have appeared during growth. The ribs are wavy and weakly nodulous, the anterior ones progressively somewhat stronger and further spaced. The anterior, flattened area has two or three radials about the periphery, but the main part has only somewhat irregular concentric ridges.

Meek compared his type species with the Upper Cretaceous *Cardium ? decussatum* Mantell, which has been well figured by Woods (1909, pl. 41, figs, 7–9, pl. 42, fig. 1) under *Pholadomya*. The New Zealand shells have much in common with these figures, especially in the flattened anterior area, with its pouting medial ridge and deep lunule. Another shell which appears to be closely related to *Procardia* is *Aporema* Dall, 1903, orthotype *Pholadomya arata* Verill from 71–134 faths. off Massachusetts. This species is figured (as *Lyonsia ?*) in *U.S. Nat. Mus. Bull.* No. 37, Pl. 45, Figs. 4, 5, 6, and Pl. 65, Figs, 133, 134. Figure 134 is almost a replica of the specimen from Terakohe. The other figures of *arata*, however, show that there is no deep lunule bound by medial ridge, which characters seem to be all that separate *Aporema* from *Procardia*.

Localities: G.S. 757, Cobden Limestone quarries, Greymouth (type of *dolichum*) (Duntroonian); Cliffs, Port Hills, Nelson (type of *maorinum*); G.S. 1286, marl limestone, Terakohe (Awamoan); G.S. 967, Waiarekan Tuff near flourmill, Maheno (= *Cardium* n.sp. of Suter in Park, 1918, p. 44) (Kaiatan).

Venericardia sp.indet.

1917. *Cardium facetum* Suter, *N.Z.G.S. Pal. Bull.* 5, p. 76, pl. 13, fig. 6.

Locality: Tuffs under upper limestone, Whitewater Creek, Trelissick Basin.

Suter's holotype of *Cardium facetum* is a fragmentary internal cast of a *Venericardia*. It bears the imprint of 15 radials, but the total number was probably about 18 or 20. Until good and undoubted

topotypes are found the species is quite unidentifiable and therefore the name must be suspended.

Although the name is useless, unfortunately it still invalidates *Cardium facetum* Zhizhchenko proposed, in 1936, for a South Russian Miocene (Chokraksk) fossil in *Travaux de l'Inst. Geol. de l'Acad. de Sciences de l'U.R.S.* tome v, p. 15.

For the sake of completeness, two species, originally described under *Cardium* but already allotted their correct place, may be mentioned:—

Glycymeris laticostata (Quoy and Gaimard).

1917. *Cardium brachytonum* Suter, *N.Z. Geol. Surv. Pal. Bull.* 5, p. 76, pl. 10, fig. 5.

1923. *Glycymeris laticostata* (Q. & G.), Marw. *T.N.Z.I.*, vol. liv, p. 66.

The name *brachytonum* can be synonymized with *Glycymeris laticostata* without any doubt. The writer, in 1923, gave the page reference as 17 instead of 76.

Venericardia subintermedia Suter.

1918. *Cardium (Glans) kaiparaensis* Marshall, *Trans. N.Z. Inst.*, vol. l, p, 272, pl. 21, figs. 5, 5a.

This is an obvious slip, as is shown on Marshall's list, p. 274, where the correct name is given, *Cardita (Glans) kaiparaensis*. It is synonymous with *Venericardia subintermedia* Suter, 1917.

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New Zealand Hepaticae (Liverworts).—IV.

A REVIEW OF THE NEW ZEALAND SPECIES OF THE GENUS *RADULA*

By E. AMY HODGSON, Kiwi Valley, Wairoa, Hawke's Bay.

[*Read before Wellington Branch, August 23, 1944; received by the Editor, August 23, 1944; issued separately, December, 1944.*]

The much discussed question as to why Dumortier's name of *Radula* should have been retained in preference to Gray's earlier name of *Martinellius,* is fully dealt with in Dr. H. Castle's "Revision of the Genus *Radula,* 1, 1936." The primary reason for the ignoring of the name *Martinellius* was the masculine termination, and when Carruthers drew attention to it in 1865, the name *Radula* was too firmly established to be altered. But there is much more to it than that. Other plants now recognised as belonging to other genera were included in *Martinellius,* thus involving more than one application of what is known as the "method of residues," with the final result that the name *Radula* "descends to the genus which has borne that name with nearly every hepaticologist since 1833."

Genus RADULA Dumortier.

Radula Dum., Comm. Bot., 112, 1822; Rec. d'Obs., 1835.

Martinellius S. F. Gray, Nat. Arr. Brit. Pl., 1, 690, 1821.

Stephanina O. Kuntz, Rev. Gen. Pl., 839, 1891. Schiffn. in Engl. & Prantl, Nat. Planfz., 1895.

Plants usually dioicous, may be autoicous or paroicous, medium, rarely small, in various shades of green, from yellowish to dark, often imparting a yellow-green stain to paper when wet, usually creeping and forming depressed mats on bark, earth, rock, mosses or filmy ferns. Stems usually pinnately to bi-pinnately branched, branches infrafoliar in origin. Leaves incubous, alternate, entire or toothed, complicate-bilobed; ventral lobe smaller, appressed to the underside of the dorsal lobe, or with the carinal portion inflated, rhizoids often arising from a mamilliform protuberance. Stipules everywhere absent. Involucral leaves usually larger than the foliage. Perianths usually acrogynous, frequently with 1–2 floral innovations, dorsiventrally compressed, plicate or smooth, oblong or with an elongated neck; lips truncate, crenate, undulate, or with a median cleft, margins sometimes winged. Capsule generally oval-cylindrical, valves with 2 layers of cells, dehiscing to the base. Androecia terminal or intercalary, bracts in pairs from 3 to about 30, antheridia usually single. Vegetative reproductive bodies present or absent.

A fairly large genus, with numerous tropical species.

Castle (1937) has divided the sub-genus *Acroradula* Spruce into 13 sections, using where fitting, the limitations and names of 4 of Stephani's 7 sub-genera, and regrouping and renaming more satisfactorily, the remaining 3.

The distinguishing features of the sub-genera and sections are as follows, the following species having been placed in their respective sections on the authority of the writer:—*R. papulosa, sainsburiana, buccinifera, plicata, levieri, silvosa, allisonii.*

Subgenus CLADORADULA Spruce.

Perianth terminal on short lateral branches only.

R. physoloba (sterile in New Zealand).

Subgenus ACRORADULA Spruce.

Perianth terminal on the main stem or on leading branches; subfloral innovations may cause it to be falsely lateral.

Section *Amentulosae* St.

Microphyllous branches present.

R. uvifera.

Section *Ampliatae* St.

Upper half of the lobule base free, rounded, and extended well across or beyond the stem.

R. grandis.

Section *Complanatae* Castle.

". . . Basal portion of the lobule free for less than one-half its length and extended usually less than half the distance across the axis."

R. papulosa.

Section *Adnatae* Castle.

". . . Base of the lobule fused to the axis for practically its entire length."

R. sainsburiana, buccinifera, plicata, levieri, silvosa.

Section *Longilobae* St.

Lobule parallel with the stem axis, and reaching more than halfway across the width of the lobe.

R. marginata, helmsiana.

Section *Densifoliae* Castle.

Leaves very crowded, lobules overlapping portion of the lobule of the alternate leaf above.

R. allisonii.

Section *Acutifoliae* St.

Leaf apices spinous or cuspidate, margins entire or toothed.

R. dentata.

In the New Zealand species there is no hard and fast line of distinction between the sections *Complanatae* and *Adnatae.*

KEY TO SPECIES.

1. Microphyllous branches present (rarely absent in *R. physoloba*)	2.	
Microphyllous branches absent	3.	
2. Microphyllous branches irregular, leaves yellowish-green, plants sterile (in New Zealand)		*physoloba*
Microphyllous branches regularly pinnate, showing on ventral side of stem, leaves glossy brown, small ribbed perianths usually present		*uvifera*

3.	Plants with marginal gemmae, sexual reproductive organs absent (as far as is known) . .	4
	Plants without marginal gemmae, bearing perianths and androecia	5.
4.	Dull green, leaves orbicular-oblong, somewhat falcate, apices much incurved, lobules much inflated, free angle much rounded	*grandis*
	Pale green, leaves sub-orbicular, lobules appressed, free angle somewhat elongated	*papulosa*
5.	Plants small, stems simple or sub-simple, tufted, (rare)	*sainsburiana*
	Plants medium to robust, stems irregularly pinnately to bi-pinnately branched, creeping ..	6.
6.	Yellow-green, leaves crowded, lobule bases overlapping alternate bases	*allisonii*
	Not or rarely yellow-green, leaves less crowded, lobule bases never overlapping alternate bases	7.
7.	Lobules elongated parallel with the stem axis, and reaching more than half-way across the width of the lobe	8.
	Lobules not elongated parallel with the stem axis, and reaching less than half-way across the width of the lobe	9.
8.	Dark-green, leaves sub-orbicular to orbicular-oblong, with a marginal rim, perianth elongate, not winged	*marginata*
	Greenish to light-brown, leaves oval-oblong, falcate, perianth winged	*helmsiana*
9	Free ventral margin directed downwards, thereby causing the leaves to appear falcate .. .	10.
	Free ventral margin in a straight line with the keel (generally speaking), leaves not falcate	11.
10.	Perianth plicate, lobule inflated with free margin folded inwards, cuticle of cells noticeably hyaline and convex	*plicata*
	Perianth tubular-elongate, lobule not or little inflated, with free angle conspicuous, cells smooth ..	*buccinifera*
11.	Leaves dentate and cuspidate, cells clear, 20–30 μ, perianth 6–8 mm.	*dentata*
	Leaves entire, cells opaque, ca. 20 μ, perianth less than 4 mm.	12.
12.	Stems to 3 cm., leaves brownish-green, approximate or contiguous, flattish, perianth gradually widening from a narrow neck	*levieri*
	Stems shorter, leaves dark-green, fleshy, imbricate, apices incurved, perianth oblong from a short neck	*silvosa*

Radula physoloba Mont.

Rad. physoloba Mont., Voy. au Pôle Sud, 256, 1843; G. L. et N., Syn. Hep. 254, 1844; Mitt. Fl. Nov. Zel., ii, 154; Fl. Tas., 1860; Handb. N.Z. Fl., ii, 530; St., Spec. Hep., 4, 213, 1910; Rod., Tas. Bry., ii, 81, 1916; Castle in Ann. Bry., 9, 46, 1936. *Rad. xanthochroma* Col., Trans. N.Z. Inst., 21, 70, 1888. *Rad. Colensoi*, St., Spec. Hep., 4, 215, 1910.

Plants apparently sterile in New Zealand, olive- to pale yellow-green, usually on bark, may be gemmiferous. Stems 1–2 cm., irregularly pinnately branched, branches very variable in size, microphyllous amenta usually present. Cauline leaves obovate-rotund, to about 1·5 mm., convex, dorsal base attached to the stem for less than half its length, slightly auricled, then curved and extending mostly beyond the stem; apex incurved, broadly rounded, free ventral margin short, recurved, the fold being continuous with the carina; lobule large oblong-ovate, carinal portion much inflated; the base attached near the edge of the stem, for about half its length, then curved away from it; the free lateral portion appressed, the free angle obtuse; apex

short, fairly straight; carina arched, oblique. Cells ca. 25 μ, marginal smaller, basal larger. " Perianth 2 mm. in length and 0·8 in width, the mouth slightly contracted, the lips with a conspicuous median cleft."

I have seen no ♂ plants that could be definitely ascribed to this species.

This species is remarkable for the varied forms of microphylly which it exhibits. Plants growing on twigs and manuka may consist almost entirely of diminutive or medium-sized leaves, which may be crowded or spaced, but usually with a stem or two of ordinary leaves which help in its identification. Microphyllous branches similar to those of *R. uvifera* may be present on the stem, or more curious still, there may be, and usually are, terminal, capitate amenta which consist of dense clusters of very short stems, tightly packed with minute bi-lobed leaves. These may be plentiful or few, on a plant, or almost entirely absent; 2, or even all 3 of these manifestations of microphylly may be present in the same gathering.

In some instances gemmae are present. These are sub-spherical, multicellular bodies and appear to be scattered indiscriminately on the stem and surfaces of the leaves. No previous mention of these gemmae appears to have been made.

Dr. Castle has a lengthy note on *R. physoloba*. He says: . . . " The cladogynous habit, as well as other important diagnostic characters, have been overlooked, with the result that the conception of the species has been extended in general to include 2 other forms which occur within the same limits of distribution. One of these is *Radula tasmanica*, which was described in the *Species Hepaticarum* by F. Stephani, in 1910. This species is always smaller, and the carinal portion of the leaves is only narrowly inflated. It is, moreover, acrogynous and must be regarded as totally unrelated to the Montagne species. Much of the material in the Stephani Herbarium, which is included under *R. physoloba* must be referred to *R. tasmanica*.' The other species which has been confused with *R. physoloba* is as yet undescribed. It is, however, of particular interest, since it includes the collections made by J. D. Hooker in Auckland." (Auckland Islands.) . . . Dr. Castle's description of this new species will be awaited with interest, especially as *R. uvifera* Tayl. was also brought from the Auckland Islands by Hooker.

Assuming that Rodway's identification of *R. tasmanica* is correct, the following note from his *Tasmanian Bryophytes* ii, is significant. " This is not a distinct species, it is the form assumed by *R. aneurysmalis* Tayl., under favourable conditions. I have specimens in which the ends of the shoots of typical *R. aneurysmalis* have grown into the typical form of *R. tasmanica*."

Stephani's reduction of *R. xanthochroma* Col., to this species is accepted by Castle, and it is very probable that *R. lycopodioides* Col., *Trans. N.Z. Inst.*, 21, 71, 1888, belongs here also.

Specimens examined include 11 from the Atiamuri, Rotorua and Taupo districts, coll. K. W. Allison, 9 on manuka, 1 on tree trunk, and 1 on twigs of *Dracophyllum* on open plain; others are, 5 from the Wairoa district, on bark in bush, E. A. Hodgson; bark of young

beech, Mt. Ruapehu, G. O. K. Sainsbury; Whakapapa Gorge, L. B. Moore; a1318, Norsewood, Herb. Colenso; 2 with *Frullania*, on bark, Tauherenikau, V. D. Zotov; Mt. Arthur, G. O. K. Sainsbury; 2 from Arthur's Pass, one growing on *Plagiochila circinalis*, the other mixed with *Dicnemon* and *Macromitrium* sps., H. M. Hodgson; on bark with *Frullania* sps., Punch Bowl, Arthur's Pass, F. MacDonald; associated with mosses on beech tree trunks in forest, Avalanche Peak, Arthur's Pass, W. Martin; Silver Peak, Dunedin, G. Simpson; also from Valley of Waipoua River, North Auckland, on manuka, K. W. Allison, and Bledisloe Park, Palmerston North, E. A. Hodgson.

The type was collected in the Auckland Islands by Hombron.

Radula uvifera (Tayl.) G. L. et N.

Jungermannia uvifera Tayl., in Lond. Journ. of Bot., 392, 1844. *Rad. uvifera* G. L. et N., Syn. Hep., 258, 1844; H. f. & T., Fl. Ant., 162, 1847; Mitt., Fl. Nov. Zel., ii, 154, 1855; Hanb. N.Z. Fl., ii, 530, 1867; St., Spec. Hep., 4, 231, 1910; Rod., Tas. Bry., ii, 82, 1916. *Radula multicarinata* G. L. et N. Syn. Hep., 258, 1844.

Plants stout, usually golden brown, creeping on bark. Stems 1–2 cm., much or little branched, amenta with small bi-lobed leaves at regular intervals on ventral side of both stem and branches, proceeding from below the lobules and usually not extending beyond the leaves. Leaves imbricate, broadly obovate-rotund, about 1·5 mm., convex when moist, with somewhat crinkly depressions when dry; dorsal base straight then curved, reaching across, to well beyond the stem, insertion very short; apices recurved, broadly rounded; free ventral margin short, a little involute, the fold being continuous with the keel; lobule ovate-oblong, base attached to near the edge of the stem for most of its length, carinal portion much inflated, the free lateral portion appressed to the dorsal lobe, free angle obtuse, apex truncate or rounded-truncate, about half the middle width; keel oblique, much arched; leaves of amenta very small, almost equally bilobed, contiguous or sub-remote. Cells ca. 20–25 μ, marginal row minute, cuticle often papillate, trigones large. Invol. leaves large, upper part rotund; lobule almost half as long as the leaf and enveloping the neck of the perianth. Perianth terminal small, subtended by innovations, easily overlooked, obovate-oblong, middle portion with numerous ridges on both faces, upper portion deflexed or decurved. ♂ bracts closely imbricate, in pairs, usually about 7, sometimes as many as 10. on ventral branches 0·9 mm. wide and quite distinct from the microphyllous amenta also present.

In the absence of perianths this species can easily be confused with *R. physoloba*. The golden brown colour is a good guide and the leaves, branches and amenta are very uniform in size and habit, thereby giving the plant a neat appearance. In *R. physoloba*, the branches may appear in all stages from microphyllous to ordinary ones, with corresponding differences in the size of the leaves.

Specimens are from: Mt. Moehau, epiphytic on kauri, 4′ up trunk, also summit of Te Moehau, L. B. Moore; Bush near Opepe, near Taupo, on tree-trunks and firewood, K. W. Allison; tree-trunks, bush on Otanepu Ridge, ca. 2,200 ft., two gatherings; on larch trunk,

Ngapuna, near Rotorua; on tree-trunks, Roto-a-kui Bush, and edge of Pukerimu Bush, east of Taupo, ca. 2,500 ft., all coll. K. W. Allison; Waiopehu Ridge, Tararua Mts., near Levin, G. O. K. Sainsbury; also in Herb. Colenso, No. 2131, and another unnumbered.

The Handbook also gives mountainous districts in North Island, common, Colenso. Lord Auckland Islands, J. D. Hooker (type).

Also Tasmania.

Radula grandis St.

Rad. grandis St., Journ. of Linn. Soc., 29, 271, pl. 28, 1892; Spec. Hep., 4, 190, 1910; Castle, Ann. Bry., 9, 1936, issued 1937.

Plants medium, dull green, sterile, gemmiferous. Stems ca. 3 cm., pinnate to bi-pinnate but not densely so. Leaves ca. 1·5 mm., the lower ones often smaller, imbricate, orbicular-oblong, somewhat falcate; dorsal base reaching well across the stem; apices much recurved, either dry or moistened, somewhat revolute; marginal discoid gemmae plentiful or sparse; free ventral margin adjoining the carina usually directed downwards for a short distance; lobule very large, rhomboid, lower portion much inflated, often with a small mamillate outgrowth, free basal portion curved and more or less overlapping the stem, sometimes extending well across it, the free lateral margin curved, often touching or over-reaching the carina of the lobule directly above it; angle obtuse; carina well-arched, oblique. Cells ca. 20 μ, apical marginal minute. Perianth unknown.

This is a fine plant. Stephani notices that it resembles small forms of *Porella stangeri,* but neither in the Linnean Journal or the *Species Hepaticarum* does he mention the marginal gemmae. These, together with the much recurved leaf-tips, and the decurved free ventral margin distinguish it from *R. physoloba* and *R. uvifera.* The dull green colour, too, is constant and characteristic, except that one specimen from Morere Bush is a brownish-green and with scarcely any gemmae.

Localities are: Mt. Ruapehu, G. O. K. Sainsbury; on earth, dry, shady bank, east of Taupo, ca. 2,500 ft., K. W. Allison; on manuka, near Atiamuri, K. W. Allison; tree trunks in Puaiti Bush, near Rotorua, and Ruahakune Bush, near Taupo, ca. 2,500 ft., K. W. Allison; on trunk of large tree, bush by Maungapoike Falls, near Wairoa, E. A. Hodgson; Waiopehu Ridge, Tararua Mts., G. O. K. Sainsbury; Wilton's Bush, near Wellington, R. Mason; three gatherings from Marlborough, localities not stated, J. H. McMahon; also from Bush near Queen Charlotte Sound, J. H. McMahon.

Stephani gives New Zealand, North Island. Castle speaks of it as "of Auckland and New Zealand." I have no knowledge of *R. grandis* having been collected in the Auckland Islands. Perhaps the name has been confused with the Auckland of the North Island of New Zealand.

Radula papulosa St.

Rad. papulosa St., in Journ. of Linn. Soc., 29, 272, 1892; Spec. Hep., 4, 189, 1910. *Rad. complanata* Dum. in Handb. N. S. Fl., 2, 530, 1867.

Plants pale olive- to pale yellow-green, creeping in mats on bark (one specimen creeping over *Papillaria crocea* attached to the bark). Stems 1–2 cm., fairly closely pinnately branched, longer branches

again bearing pinnules. Leaves slightly to closely imbricate, subcircular, slightly convex, margins somewhat recurved or plane, occasionally hyaline, often crenulate and gemmiferous, being edged with irregularly shaped, multicellular bodies, originating from the marginal cells; the free dorsal part extending across the stem and overlapping the basal portion of the opposite leaf; the free portion of the ventral margin more or less in a straight line with the keel. Lobule large, rectangular-rhomboid, somewhat oblique, scarcely arched, base straight, attached to the stem axis for about half its length, the free portion overlapping the stem, but rarely reaching half way across it; apex truncate, free angle obtuse, often somewhat elongated; a small, brownish, mammilate outgrowth sometimes present on the mid-carinal portion. Cells rounded-hexagonal, rather obscure, ca. 20–25 μ; no trigones. Fructification unknown. Androecia in 3–4 pairs on small branches, may be basal or terminal, bracts about half the size of the ordinary leaves or less.

The sub-circular imbricate leaves with gemmiparous margins make this plant easy of recognition.

As Stephani points out in the Linnean Journal, his *R. papulosa* is most probably the plant described in the Handbook as *R. complanata*, a gemmiferous plant of the Northern Hemisphere. *R. complanata* is not the same species as *R. papulosa*, as is shown by English specimens in my possession, and it is not likely that both species occur in New Zealand.

My specimens are all local: Base of cabbage tree (*Cordyline australis*), Alton, near Wairoa. In bush Te Tiki, ca. 1,500 ft., inland from Wairoa; in bush, Terapatiki, near L. Waikaremoana, two gatherings, one ♂; in bush by Maungapoike Stream, near Wairoa; also in Herb. Colenso, No. a1643*.

The Handbook plant is from Ruakawa, H. B., coll. Colenso. Stephani gives no definite locality for his type.

Radula sainsburiana Hodgson and Allison sp. nov.

Paroica, minima, caespitosa flavo-rufescens. Caulis ad 1·3 cm., longus, simplex vel parum ramosus. Folia caulina ovato-elliptica, parum oblique-patula, concava; basi ampliato, caulem bene tegente et supra extento; lobulus late ovatus, inflatus deinde appressus vel involutus, apice angusto, excurrente in marginem incurvum folii. Folia ramea minora, erecto-patentia, valde concava; carina bene arcuata, sinuata. Cellulae ca. 20 μ, parietibus incrassatis. Perianthia innovata, oblonga 1·5 mm. x 0·1 mm., ore truncato. Androecia infra perianthium, bracteis 3–4 jugis.

Plants paroicous, very small, pale yellow-green to reddish-brown with tints of rose, tufted, with *Sphenolobus perigonialis* (also rose-tinted). Stems to about 1·3 cm., simple or little branched. Leaves concave, ca. 0·6 mm., loosely imbricated, spreading, similar in appearance to those of *Lejeunia;* dorsal lobe oval to ovate-rotund, base arched, extending beyond the stem and overlapping a small portion of the alternate lobe above, the free ventral margin directed upwards, slightly incurved, the fold continuous with the carina; lobule more

* A further locality is Bledisloe Park, Palmerston Nth., E. A. H., Oct., 1944.

or less broadly ovate, base seems to be attached to the stem for most of its length, line of attachment at varying distances from the margin of the stem, carinal portion inflated, the free side appressed; apex narrowed and usually continuous with the slightly incurved ventral margin of the lobe, no rhizoidal outgrowths. Carina strongly arched, sinuate. Cells ca. 20 μ, walls thick, cuticle papillate distinctly showing along the edge of the carina; trigones confluent. Branch leaves more erect, lobes may be much smaller, with the appearance of being laterally extended; lobules remaining much the same size. Invol. leaves larger than the foliage, lobule longly obovate, extending half way or more across the width of the lobe. Perianth oblong, ca. 1·5 mm. x ca. 0·8 mm., subtended by an innovation and 3 or 4 perigonial bracts with closely imbricated lobules; mouth two-lipped, truncate. (Two inflorescences seen.)

This little species is distinct in its small size, pale colour, spreading leaves and paroicous inflorescence.

The habitat seems to have been on rock; locality, creek-bed, Mt. Ruapehu, coll. G. O. K. Sainsbury.

A duplicate of the type is in the Herbarium of the Plant Research Bureau, Wellington.

Radula allisonii Castle.

Rad. Alstonii Castle in Hep. Select. et Crit., in *Ann. Bry.*, 8, 1935, corrected to *Rad. Allisonii* in *Ann. Bry.*, 10, 130, 1937.

Plants medium to robust, pale yellow-green, densely creeping, often mixed with *R. buccinifera*, usually on bark. Stems ca. 1·5–2·5 cm., irregularly pinnately ramose, branches of varying length. Leaves large on the main stem, ca. 1–1·2 mm., medium to small on the branches, imbricate; dorsal lobe concave, oval, with the rounded apical portion irregularly recurved or even revolute (when dry), base from a straight insertion, reaching beyond the stem about 1·5 mm., and overlapping the base of the alternate leaf above; the free ventral margin rarely directed downwards, in the case of the smaller branches, may be directed upwards. Lobule outstanding in both size and shape, not inflated; base attached to the stem for about half way in a more or less straight line, then expanding broadly in a curve which mostly overlaps the basal portion of the alternate lobule above, and is continued, to form the free lateral margin of the lobule; the free angle usually obtuse, may be acute or acuminate; apex lunate or sinuous, rarely truncate; carina oblique, fairly straight; tufted rhizoidal outgrowths may be present. Cells ca. 22 μ, cuticle papillate, trigones minute or absent. Invol. leaves sub-erect, lobule reaching about half the length of the lobe. Perianth oblong, ca. 3·5–4 mm., x ca. 0·9–1 mm., margins partially or entirely irregularly winged, wings to 0·1 mm.; apex often decurved, mouth truncate, straight to sub-crenate; subtended by innovations. ♂ bracts small to medium, on branches of varying lengths, both pinnae and pinnulae.

The pale colour, crowded leaves, with large lobules deflected from the stem axis, and winged perianths, are the distinguishing features of this notable species, of which the distribution as far as is known, is restricted to the Central North Island Plateau District. Of the 15 specimens in Mr. Allison's herbarium, 7 are from tree trunks, Puaiti

Bush, South of Rotorua; 2 from tree trunks Pukerimu Bush, ca. 2,500 ft., East of Taupo; 2 from rock, East of Waiotapu Valley, ca. 1,600 ft., Rotorua Co.; tree trunk, Roto-a-Kui Bush, East of Taupo; tree trunk, Ruahakune Bush, near Taupo; on earth, under manuka (*Leptospermum scoparium*), near Atiamuri; on bark, bush at edge of Urewera; also on bark in bush, Taihape Domain, E. A. Hodgson.

Radula marginata (Tayl.) G. L. et N.

Jungermannia marginata Tayl., in Lond. Journ. of Bot., 566, 1844. *Rad. marginata* G. L. et N., Syn. Hep., 261, 1844; Mitt., Fl. Nov. Zel., ii, 154, 1855; Handb. N.Z. Fl., ii, 530; St., Spec. Hep., 4, 230, 1910.

Plants dark green, rarely fruiting, in depressed mats on rock, earth, bark or logs. Stems to about 3 cm., little or much branched. Leaves orbicular-oblong, imbricate, slightly convex, margins having a thickened, somewhat horny appearance, due to the differentiated cells; base of dorsal lobe about half attached to the stem, then rounded and extending most of the way across it; free ventral margin in a straight line with the carina, which is short, though somewhat longer in the Marlborough specimen; lobule ovate-elongate, parallel with the stem, angle obtuse, base about a quarter attached to the stem; tufted rhizoids may be present. Cells obscure, marginal minute and crowded, median ca. 20–25 μ, trigones small or absent. Invol. leaves more oblong than the cauline, with an even larger lobule. Perianth ca. 4·5 mm., including the neck, 0·9 mm. wide, lips truncate. ♂ bracts small, in 4–5 pairs, on very short branches, or at the bases of longer ones.

The only fruiting plants I have seen are from Waihau Bay or Raukokore River, Bay of Plenty, coll. G. M. O'Malley, No. H 638 Herb. Allison; bare rock in stream, Waipoua Forest, K. W. Allison.

The large, rounded, deep-green leaves with a noticeable rim, together with the unusually tall lobule, enable this species to be easily recognised.

Other localities are: Common on rock in shaded wooded gullies, Mt. Wellington lava field, Auckland, E. B. Ashcroft, comm. K. W. Allison; Titirangi, Auckland, E. D. Swanberg; Shortland, Thames, T. Kirk, 1868, No. 6071, P. R. B. Herb.; on log between wet cliffs, bush at Maungapoike Falls, Wairoa; on earth mound, Morere Bush, E. A. Hodgson; upper Tiritea River, V. D. Zotov, No. 6889 P. R. B. Herb.; wet rock, Wilton's Bush, Wellington, R. Mason; Kapiti Island, with *Plagiochila stephensoniana*, No. 4077 P. R. B. Herb., A. H. Wilkinson; Red Hills, Marlborough, ♂, collector uncertain.

The type was from the Bay of Islands, coll. Hooker. The Handbook also records it from Nelson, coll. Mantell.

Radula helmsiana St.

Rad. Helmsiana St., 4, 231, 1910.

Plants medium, brownish-green when fresh, usually light brown when dry, creeping on bark. Stem 1–1·5 cm., little or much bipinnately branched, crowded or extended. Leaves oval-oblong, inclined to be falcate, contiguous or more usually a little imbricate, may be flat, when the plant greatly resembles *Lopholejeunia plicatiscypha*, or bent or curved, generally upwards; ca. 0·9–1·1 mm.; x ca. 0·7 mm.; dorsal base sub-truncate, less than half attached to the stem, extending rarely less than half-way across, but not beyond it;

free ventral margin in a straight line with the carina, or deflected somewhat, from a wide sinus; lobule large, rhomboid-ovate, often reaching beyond the carina of the lobule above it; base long, attached to the stem for less than half its length; the free angle obtuse; carina oblique, only slightly arched. Cells, marginal ca. 12 μ, median ca. 20 μ, with a dotted appearance; trigones minute. Invol. leaves oblong, may be twice as long as broad, lobule reaching about three-quarters across the width of the lobe. Perianth ca. 2·4 mm. long, oblong-lanceolate, margins winged, usually widest below the middle, ca. 0·8 mm. excluding the wings; wings ca. 0·1 mm. or less, may be undulate; mouth ca. 0·5 mm. wide, two-lipped, lips with a median cleft. ♂ stems all lying in the same direction, bracts to 30 or more pairs, though few appear to contain antheridia; lobe erect, the upper part spreading, lobule almost as large as the lobe.

There is an element of doubt about this identification, as the leaves of Stephani's plant, which unfortunately was a sterile one, are described as " subrotunda "; but the large, elongate lobule is the same. It is just possible that Stephani has mistaken a discoloured specimen of *R. marginata* for a new species. If there really are 2 separate species involved, then a new name must be found for the North Island plant (described above).

Distinct from *R. allisonii* in the differently shaped lobule, the less crowded, oval-falcate leaves; and the perianths though winged, are not truly oblong as in that species, but narrowed towards the base and apex, while the lips are cleft in the middle.

Localities are not numerous. Common in bush at Morere Hot Springs, between Wairoa and Gisborne; " McKinnon's " Bush, bush at Maungapoike Falls, both near Wairoa, E. A. Hodgson; forest between Lake Rotoehu and coast, K. W. Allison; Puaiti Bush, near Rotorua, K. W. Allison; Wilton's Bush, Wellington, 2 gatherings, R. Mason; Bledisloe Park, Palmerston North, on bark, E. A. Hodgson.

Radula plicata Mitt.

Rad. plicata Mitt., Fl. Nov. Zel., ii, 154; Handb. N.Z. Fl., ii, 530, 1867; St., Spec. Hep., 4, 213, 1910; Pears., Univ. Cal. Pub. Bot., 10, 1923.

Plants dull green, faintly brownish, closely matted. Stems 2–3 cm., pinnately to bi-pinnately branched. Leaves 0·8–1 mm., imbricate, convex, somewhat falcate; dorsal lobe with a somewhat truncate base produced into an ample curve which may considerably over-reach the stem; apex recurved; free portion of the ventral margin extending downwards from the oblique lobule at approximately a right angle; lobule medium, lower portion inflated, longly decurrent, sub-rhomboid, base adnate with the stem for practically its whole length, the free latteral marginal area usually folded inwards over the inflation, which may be narrowed towards the rounded-truncate apex; the free angle obtuse; carina strongly arched or sinuate, oblique. Cells ca. 20 μ, larger at the base, trigones very small; cuticle convex and hyaline, showing along the edge of the carina and the backward fold of the upper part of the dorsal lobe. Invol. leaves somewhat smaller than the cauline, obovate, dorsal lobe not produced downwards, lobule shorter and broader than the cauline, flat. Perianth ca. 3·5 mm., oblong, gradually widening from a narrow neck, with three full-

length plicae on the dorsal and 2–4 on the ventral face. Androecia in 4–6 pairs on short branches, or intercalary on longer ones. Stephani speaks of the branches as very long, sometimes occupying the whole plant.

The plicate perianth will always distinguish this species which, as Mitten points out, very closely resembles *R. buccinifera*. Another difference is that the lobule in *R. plicata* is longer, that is, the free angle is further removed from the stem, and the carinal portion is more inflated. The leaves are less, but more regularly recurved, and lack a certain lustre natural to those of *R. buccinifera.*

I certainly agree with Pearson, who wrote about Setchell's plant from Mamaku, that Stephani's note about the perianth folds being not very noticeable, and only on the older branches,, is incorrect.

Fruiting plants seen are from Karamea,, Nelson, coll. Miss Foot, and Dreamlands, Waitakere Ranges. Auckland, L. B. Moore, No. 24763, P. R. B. Herb. A ♂ specimen, epiphyllous on *Trichomanes elongatum* is also from Dreamlands, No. 24729, P. R. B. Herb., coll. L. B. Moore. A sterile plant enveloping stems of *Weymouthia cochlearifolia* (moss), is from near Fox Glacier, coll. Mrs. Knight; while 2 sterile plants which I think belong here, but cannot say with certainty, are from Wilton's Bush, Wellington, R. Mason, and Little Barrier Island on *Hypopterygium filiculaeforme*, also a moss, coll. W. M. Hamilton.

The type locality is given as Auckland, coll. Dr. Sinclair.

Radula buccinifera (Tayl.) G. L. et N.

Jungermannia buccinifera Tayl., Hep. Antarct., in Lond. Journ. of Bot., 580, 1844. *Rad. buccinifera* G. L. et N., Syn. Hep., 261; Mitt., Fl. Nov. Zel., ii, 154; Fl. Tas., 1860; Handb. N.Z. Fl., ii, 530; Rod., Tas. Bry., ii, 81, 1916; St., Spec. Hep., 4, 227, 1910.

Plants dioicous, in compact, spreading mats when creeping on bark or rock, glossy golden brown to olive green, sometimes gemmiferous. Stems 2–3 cm., freely branched, branches and branchlets short or long, leaves on the short ones may be smaller and more erect, but not minute. Cauline leaves convex, ovate-falcate, less than 1 mm., antical base more or less truncate, then curved, often extending beyond the stem; apices irregularly recurved, giving the leaves a collapsed look; leaf edge may be sinuate or more rarely still, with a blunt serration or other marginal irregularity; free ventral margin directed downwards, forming a sinus with the lobule; lobule medium or small, vertically rhomboid, base slightly inclined towards the middle of the stem, long, attached to the stem for most of its length, straight or a little curved at the top; the free apical angle, obtuse or bluntly acute, may be somewhat elongated, or curved in the direction of the stem; usually flat, may be inflated in the lower portion, or bulging, on the branches; carina oblique, more or less arched. Cells ca. 10–20 μ, marginal minute, cuticle with a hyaline, low papilla. Invol. leaves obovate, lobule with a very long base. Perianth ca. 3 mm., narrow-tubular, widened somewhat near the apex, mouth crenate or truncate; sterile perianths shorter and broader.

Perigonal bracts usually in 3 or 4 pairs, alternating with 3 or 4 "proper" leaves on fairly long branches, or on short, purely ♂ branches; lobule about half the size of the lobe.

A plant from bush by Makaretu Stream, near Wairoa, growing on bark, has the lobules filled with multicellular septate gemmae. When moistened these float out into the concave surface of the leaf. Another plant, on firewood, Bay of Plenty, coll. K. W. Allison, is ♂, and has gemmae in the lobules of the " proper " leaves alternating with the perigonal bracts. These are shorter than those of the Wairoa plant. A third plant, ♂, from near Atiamuri, on earth under manuka, has but a few gemmae in some of the lobules.

Specimens examined include 23 from Taupo, Rotorua and Atiamuri districts, habitats being bark of tree-trunks and branches, tree-ferns, rocks, on logs, on earth under manuka, one on Mt. Ngongataha creeping over fronds of *Hymenophyllum demissum*, also one on bare bark of rimu, 6–8 feet from ground, between Lake Roto-ehu and coast, Bay of Plenty, all coll. K. W. Allison. Other localities are: Bush by Lakes Waikaremoana and Waikare-iti, on bark and *Hymenophyllum* sp. respectively; Morere Bush; Maungapoike Falls Bush, enveloping *Polytrichum juniperum*, all coll. E. A. Hodgson; Mt. Maungapohatu, B. Teague; Mangahao Headworks on *Cyrtopus setosus*, G. O. K. Sainsbury; headwaters of east branch of Hawdon River, North Canterbury, H. M. Hodgson; with *Plagiochila lyallii* near Fox Glacier, Mrs. Knight.

The Handbook also gives Otago, Hector and Buchanan.

The type was collected in Tasmania by Hooker. Also found in Australia.

Radula dentata Mitt.

Lejeunia dentata Mitt. in Fl. Nov. Zel., ii, 159, 1855. *Radula dentata* Mitt., M. S.; Handb. N.Z. Fl., ii, 1867; St., Spec. Hep., 4, 156, 1910.

Plants medium, terrestrial, glossy, light brown or olive green. Stems to about 3 cm., rather closely pinnately branched. Leaves imbricate, convex, varying in size, usually less than 1 mm.; dorsal margin 1–3 spinous-toothed, or dentate or sinuous, the free basal portion reaching from about one-third to half the distance across the stem; apex recurved with 1–3 spinous teeth; free ventral marginal portion entire or toothed, not directed downwards from the lobule; lobule ovate, oblique, carinal portion much arched and inflated, the free margin appressed to the lobe, the free angle usually obtuse. Cells ca. 20–30 μ, no trigones. Invol. leaves in 3 pairs, the uppermost much larger than the cauline, the lower pairs smaller, entire or cuspidate or with few teeth. Perianth very long, 6–8 mm., from a narrow tubular base, middle width ca. 0·5 mm., mouth slightly wider, truncate.

I cannot help but think that *R. cuspidata* St., *Spec. Hep.*, 4, 156, also from the Great Barrier Island, is only a form of *R. dentata*. The only difference of any possible consequence that I can infer from Stephani's description and drawing, is that *R. cuspidata* lacks the marginal teeth; the shape of the leaf and lobule and the copious branching are apparently the same, while the perianth is not mentioned at all; but in some of the lower leaves of the Moehau plant the marginal teeth are almost obsolete, and Stephani himself says under *R. dentata*, " Die Blattzähne variinen ausserordentlich in Anzahl

wie in Grösse und es kommen sogar völlig gansrandige Blätter vor." Stephani's leaf-outline, with its longly cuspidate incurved apex is strikingly similar to leaves of *R. dentata*.

A well-marked species. Localities: Great Barrier Island (in Kirk's collection), mixed with *Blepharostoma* sp., and *Chiloscyphus triacanthus;* Te Moehau Mt., ca. 2,000 ft., also mixed with *C. triacanthus,* L. B. Moore; growing in short, thick clump of *Plagiochila* on sandy creek bank, Waipoua Forest, K. W. Allison.

Stephani gives New Zealand and New Caledonia. The type locality is given as Auckland, coll. Sinclair.

Radula levieri St.

R. Levieri St. Spec. Hep., 4, 227, 1910.

Plants usually dioicous, olive-green to light brown, straggling or compact on bark, rock, earth, or growing on, or mingled with, mosses or other hepatics. Stems ca. 3 cm., thin, reddish-brown or darker, branched pinnately, branches of varying lengths. Leaves 0·9–1 mm., usually flat or almost so, little altered when dry, elliptic or elliptic-orbicular, approximate, contiguous or less often, slightly imbricate; dorsal line of attachment straight, free portion curved a little but not extending to the middle of the stem; free ventral margin in a straight line with the carina, not proceeding downwards; lobule small, sub-quadrate, base long, mostly joined to the stem, angle obtuse or sub-acute; carina oblique, straight or slightly inwardly curved, longly decurrent; branch leaves usually smaller; cells 6-sided, opaque, ca. 20 μ, trigones absent or very small. Invol. leaves smaller than the cauline, oval, lobule reaching almost across the width of the leaf. Perianth to 3·5 mm., gradually widening from a narrow-tubular neck, or oblong from a less elongated neck, mouth truncate or crenate. ♂ bracts in a few pairs on short pinnate branches, or numerous on long ones, imbricate, more erect than the ordinary leaves, lobules imbricate reaching half to two-thirds up the lobe.

A plant from clay bank, Otari Reserve, Wellington, coll. N. Kemble Welch, comm. K. W. Allison, is definitely monoicous, but this does not appear to be usual.

I think it is very probable that *R. strangulata* Tayl. in *Lond. Journ. of Bot.,* 1846, *Syn. Hep.,* 730, but omitted from the *Flora Novae Zelandiae* and the Handbook, is the ♂ plant of *R. levieri* St. Colenso draws attention to this species in *Trans. N.Z. Inst.,* 21, p. 71. It was collected at Bay of Islands by Hooker.

R. levieri can be distinguished from *R. buccinifera* by the flattish non-imbricate, non-falcate leaves, whose dorsal bases do not reach across the stem, which thus appears as a wavy line between two rows of alternate leaves.

North Island localities are numerous, extending from North Auckland to Wellington. South Island stations are as follows: Bay of Many Coves, Marlborough; Banks Peninsula, both coll. H. M. Hodgson; watershed of Kaituna Creek, Nelson, G. Simpson and J. S. Thomson; water-race in Silverstream Valley, also Whare Flat, Dunedin, G. Simpson and J. S. Thomson; near Dunedin, M. Finlayson.

Stephani's type was from Westland, coll. Helms; also collected by Beckett.

Radula silvosa Hodgson and Allison sp. nov.

Dioica fusco-virida, implicata. Caulis ca. 1 cm., irregulariter pinnatus vel bi-pinnatus. Folia caulina imbricata, carnosa, elliptica, ca. 0·8 mm. longa, vel late sic; apico incurvo, basi breviter accreta, supero libero, ampliato, caulem tegente; lobulus sub-quadratus basi ad marginem caulinis longe accretus, supra basin interdum leviter ampliatus; angulo obtuso apice oblique truncato; carina obliqua, substricta longe decurrente. Cellulae ca. 20 μ, obscurae. Perianthia utrinque innovata, oblonga, 1·5–2·5 mm. x 0·8–1·1 mm.; ore truncato vel crenato. ♂ rami breves, pinnati remotiuscule, bracteis 3–4 jugis.

Plants in layered mats on earth mounds and overground roots usually in deep shade, often in association with the mosses *Homalia pulchella* and *Eriopus brownii,* dark green, fleshy when fresh. Stems ca. 1 cm., irregularly pinnately to bi-pinnately branched, sub-floral innovations of varying lengths. Leaves imbricate, fleshy, oval to oval-rotundate, apices may be incurved; dorsal base shortly attached, then arched and usually reaching more than half-way, sometimes wholly, across the stem, and often covering a portion of the alternate lobe above it; free ventral margin not, or rarely, directed downwards, usually in a direct line with, or continuing the curve of, the carina; lobule not inflated, triangular-rhomboid, base long, sometimes reaching 3·5 mm. in length, the upper, free part sometimes slightly overlapping the stem; the free angle obtuse or sub-acute, the apex obliquely truncate, always shorter than the base and never quite parallel with it; carina oblique, scarcely arched, longly decurrent. Cells hexagonal, ca. 20 μ, the lumen partly or wholly filled with dark, opaque chloroplasts. Trigones O. Invol. bracts larger, lobule elongate, reaching about three-quarters of the way across the width of the lobe. Perianth 1·5–2·5 mm. x 0·8–1·1 mm., occasionally somewhat widened towards the mouth, flat, with traces of rudimentary wings; mouth truncate or crenate. (In a specimen from Morere bush, the perianths are funnel-shaped with crinkled mouths.) ♂ bracts in 3 or 4 pairs on short pinnate branches.

Nearest to *R. levieri,* from which it is sometimes difficult to distinguish in the dry state, the shape and structure of the lobe and lobule being similar in both species. But the leaves of *R. silvosa* are more crowded, with the dorsal lobe overlapping the stem, and the whole plant is stouter and more compact. The perianth, too, is shorter and broader, without the elongated tubular neck of *R. levieri,* though occasionally the perianths do approach those of the latter species in shape. When freshly gathered, the dark green, fleshy leaves are a great help in identifying the plant.

Not uncommon in bush in Wairoa County. The type is from Te Tiki Station, Wairoa, ca. 1,500 ft., No. 24766 P. R. B. Herb. Also from Ohope, near Whakatane, H. M. Hodgson, and Wilton's Bush, Wellington, R. Mason.

Additional.

In *Species Hepaticarum* 4, 190, Stephani ascribes the Norfolk Island species, *Radula mittenii* St., to New Zealand. I have not yet met with any plant that corresponds with his description and drawing. According to these, the plant may be 5 cm. long, the leaf re-

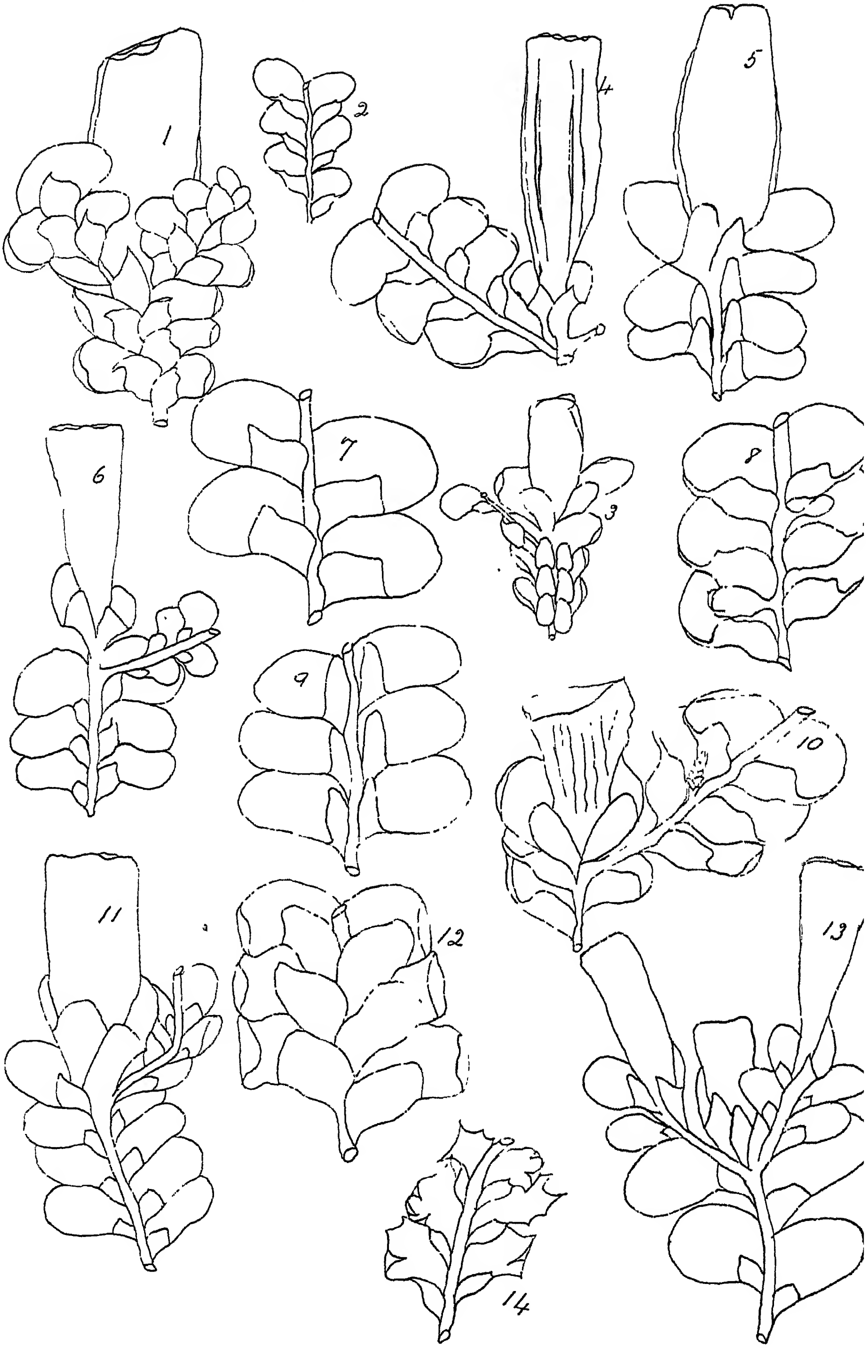

FIG. 1—*R. allisonii.* FIGS. 2–3—*R. sainsburiana.* FIG. 4—*R. plicata.* FIG. 5—*R. helmsiana.* FIG. 6—*R. buccinifera.* FIG. 7—*R. papulosa.* FIG. 8—*R. physoloba.* FIG. 9—*R. marginata.* FIG. 10—*R. uvifera.* FIG. 11—*R. silvosa.* FIG. 12—*R. grandis.* FIG. 13—*R. levieri.* FIG. 14—*R. dentata.*

Facing page 286.

sembling that of *R. levieri,* and the perianth that of *R. buccinifera,* but it differs from both these species in the lobule which has the free portion of the lobule base ampliate, and partly covering the stem. A specimen in Herb. Petrie, No. 131, determined by Stephani as *R. mittenii,* is *R. levieri.*

Radula albipes Col., *Trans. N.Z. Inst.,* 21, p. 71, 1888, is *Lejeunia nudipes* Tayl, according to Stepheni in his Revision of Colenso's New Zealand Hepaticae, and from the description, this appears to be correct.

ACKNOWLEDGMENTS.

In concluding I gratefully acknowledge the loan of Mr. K. W. Allison's entire collection of Radulas, and of still further consignments of liverworts from the Herbarium of the Plant Research Bureau. Thanks are also extended to Miss L. B. Moore for helpful criticism of the manuscript.

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CORRIGENDA.

The following typographical corrections should be made to Hodgson, E. A., 1944. A Review of the N.Z. Species of *Plagiochila. Trans. Roy. Soc. N.Z.,* vol. 73, pt. 4:—

Page 291, line 6: should read "the whole length of the stem . . . ."

Page 291, line 17: should read ". . . . strongly-toothed."

Vol. 74, Part III, pp. 288–293, Plate 39.

The Classification and Reproductive Organs of New Zealand Land Planarians,

PART I.—*GEOPLANA GRAFFII* DENDY AND *ARTIOPOSTHIA HOWESI* (DENDY).

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[*Read before Otago Branch, May 9, 1944; received by the Editor, May 15, 1944; issued separately, December, 1944.*]

Material.

The material on which this paper is based includes: (1) Material collected in New Zealand and presented to the Zoology Department, and (2) selected specimens from Dendy's type material deposited by him in the British Museum. Sir William Benham examined and made general notes on all Dendy's material in 1937, and he has kindly made these notes available to the writer. The British Museum specimens examined by the writer were selected from the collection on the basis of Benham's notes.

Nomenclature.

The nomenclature of the New Zealand land planarians is somewhat complicated by the fact that Dendy did not designate holotypes for most of his species, therefore there are a number of syntypes and the position is further complicated by the subsequently proved identity of several of Dendy's species and varieties, and by the fact that in other cases more than one species is included among the syntypes of a single species of Dendy.

Geoplana graffii Dendy.

1895. *Geoplana agricola* Dendy, *Trans. N.Z. Inst.*, vol. xxvii, pp. 184–185.

1895. *Geoplana inequalistriata* Dendy, *Trans. N.Z. Inst.*, vol. xxvii, pp. 182–183.

1896. *Geoplana iris* Dendy (in part), *Trans. N.Z. Inst.*, vol. xxviii, p. 213.

1897. *Geoplana graffii* var. *occidentalis* Dendy, *Trans. N.Z. Inst.*, vol. xxix, pp. 260–261.

1901. *Geoplana graffii* var. *nodosa* Dendy. *Trans. N.Z. Inst.*, vol. xxxiii, pp. 227–228.

1901. *Geoplana graffii* var. *wharekauriensis* Dendy, *Trans. N.Z. Inst.*, vol. xxxiii, pp. 226–227.

Locality. *G. graffii* lives under stones and wood in damp situations and is one of the commonest land planarians found in the Dunedin district. It is probably equally common elsewhere judging by the number of varieties found by Dendy (1900) in various parts of Otago, Canterbury and the Chatham Islands.

External Characters. The worm is fairly large, broad, and tough, and is one of the few land planarians which can be kept alive under laboratory conditions for a long period. The average length of a living specimen is about 45 mm. The dorsal surface is greeny-brown speckled with long slits of a bluish-white colour, which often gives the appearance of iridescence. There is a broad median stripe varying in colour from yellow to tan, with a dark line on each edge. Marginal bands are paler than the ground colour and are speckled. The ventral surface is paler than the dorsal, with dark brown speckles and a pale median stripe.

The mouth is approximately half way along the ventral surface, and the genital pore is nearer the mouth than the posterior end.

Eyes are very numerous along both sides and round the anterior end.

This planarian is easily recognised by its broad shape, median stripe, and the characteristic bluish-white slits on the dorsal surface, which tends to look iridescent.

Reproductive Organs. The genital atrium is small, and is separated by a muscular partition into male (m.at.) and female (f.at.) parts. The amount of separation varies, presumably according to the amount of contraction of the animal on fixing. Into the male atrium open the male duct and an accessory gland and into the female open the oviduct (od.) and an accessory gland.

Paired ovaries lie in the usual ventral anterior position. The two oviducts join together behind the atrium and enter a wider glandular canal (g.c.), which receives numerous shell glands (sh.g.) and opens into the female atrium.

The numerous testes are arranged in two lateral bands between the oviducts and the lateral margins. They extend from the region of the ovaries to the atrium. The vasa efferentia arise from the ventral surfaces of the testes and enter a longitudinal vas deferens (v.d.) one on each side extending from the pharynx to the penis bulb (b.p.). Here the two ducts turn dorsally and join to form a short, narrow, glandular seminal duct (d.s.) which enters the massive cylindrical penis bulb enclosing the wide seminal vesicle (v.s.) with its narrow opening into the male atrium. There is no penis papilla.

The two accessory glands are a constant feature of *G. graffii*, having been found in all fully-grown specimens examined at various times of the year, and so far as can be judged, are not seasonal. I have examined specimens collected at fortnightly intervals for four months of the year, and in all of these the accessory glands were always well-developed in fully-grown worms. The structure of both accessory glands is essentially the same. Each lies in its own muscle mass, which can easily be separated from the surrounding parenchyma. The gland consists of a wide reservoir (re.) which in mature worms contains lumps of secretion. This is followed by a narrow coiled duct (d.c.) with valves (v) at intervals along its length. The coiled duct is surrounded by a wide sheath of circular muscles and enters a large, muscular vesicle (v.m.), which opens into the genital

atrium through a narrow duct of varying length. The coiled duct and the muscular vesicle are both lined with ciliated epithelium. The accessory gland has no connection with the gut, as is often the case with the bursa copulatrix.

The function of the accessory glands is obscure. They somewhat resemble the bursa copulatrix of land planarians which is a receptacle for sperms received during copulation, the sperms remaining there only for a short time before passing up the oviducts to fertilize the ripe eggs. Von Graff (1899, p. 178) describes for the genus *Artioposthia* receptacula seminis which in their structure resemble very closely the accessory glands of *G. graffii*. That of *A. fletcheri* is especially similar, with its muscular ring (cl.) where the narrow, muscular, coiled duct enters the wide terminal vesicle. Actually the accessory glands of *G. graffii* most closely resemble adenodactyli except for the fact that the latter project *externally* from the atrial wall while the former lie *within* the atrial wall. The reservoir duct and glands of adenodactyli are related to cocoon formation, and the production of abundant secretion by the reservoir of the accessory glands suggests the same function here, with the muscular coiled duct and valves regulating the supply of secretion. On the other hand, in stained preparations, what appeared to be sperms were often seen in the terminal vesicle of the female gland, but no great reliance can be placed on this without special selective staining. It is hoped that with the further study of living planarians the function of the accessory glands in this species will be more clearly understood.

Remarks. The following specimens from Dendy's collection in the British Museum have been sectioned and found to have the same internal structure as *G. graffii*. Externally they are very similar, and Dendy, in describing the external characters only, suggests that each one closely resembles *G. graffii*, the only differences between the species or varieties being slight variations in colour or markings. I therefore include in the species *G. graffii* the forms identified by Dendy as follows:—*G. agricola*, *G. iris* (in part), *G. inequalistriata*, *G. graffii* var. *nodosa*, *G. graffii* var. *occidentalis*, *G. graffii* var. *wharekauriensis*.

A number of species and varieties are tentatively included by me in the species *graffii*. As they were not among the British Museum specimens forwarded to me, I have only Dendy's description of the external features for comparison. Externally they all closely resemble *G. graffii* and such differences as do occur are not so distinctive as those which are found between some of the species and varieties now *known* to be *graffii*. As only one, or at the most two, specimens are recorded for each species or variety, the writer feels that there is insufficient grounds to warrant the formation of a new species or variety. I therefore tentatively include in the species *G. graffii* until such time as the type material can be examined, the forms identified by Dendy as follows:—*G. fagicola* (1900, p. 233, one specimen); *G. gelatinosa* (1895, p. 186, one specimen); *G. hamiltoni* (1895, p. 186, one specimen); *G. jacksoniana* (1897, p. 262, one specimen); *G. graffii* var. *castanea* (1900, p. 225, two specimens); *G. graffii* var. *dorso-mar-*

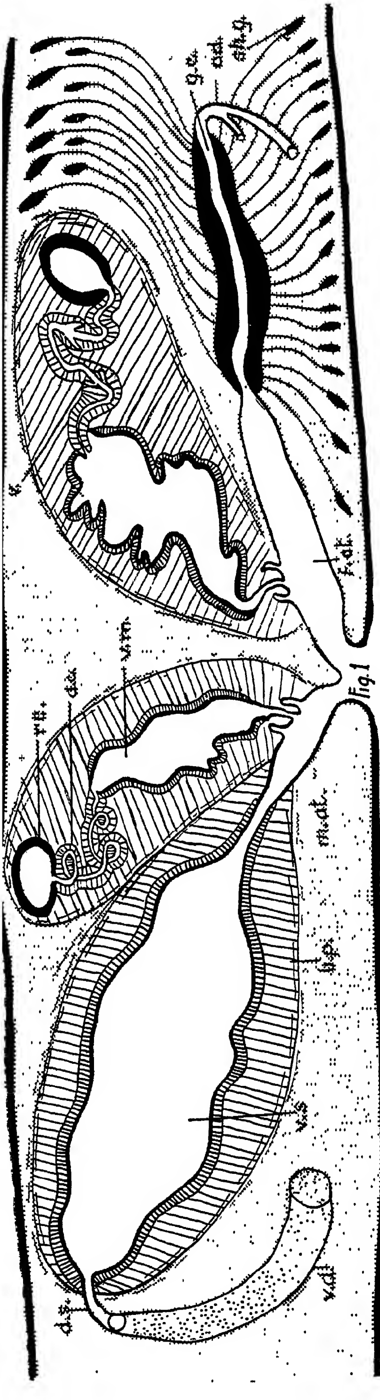

FIG. 1. Diagrammatic longitudinal sagittal section of *G. graffii.*

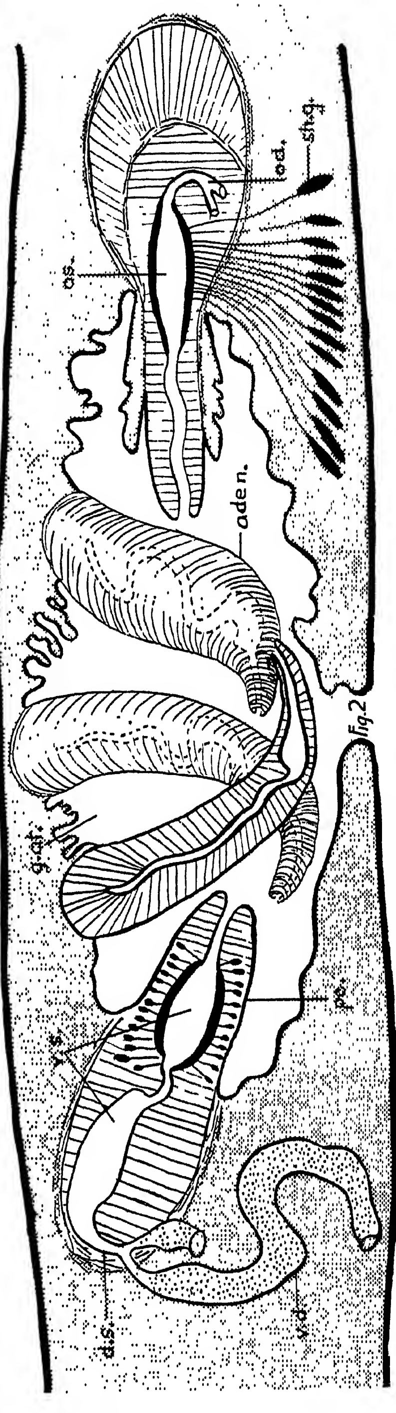

FIG. 2. Diagrammatic longitudinal sagittal section of *A. howesi.*

Aden., adenodactylus; b.p., penis bulb; d.c., ciliated duct; d.s., seminal duct; f.at., female atrium; g.at., genital atrium; g.c., glandular canal; m.at., male atrium; od., oviduct; os., ovisac; pe., penis; re., reservoir; sh.g., shell gland; v., valve; v.d., vas deferens; v.m., muscular vesicle; v.s., seminal vesicle.

morata (1900, p. 228, one specimen), *G. graffii* var. *clintonis* (1900, p. 228, two specimens); *G. graffii* var. *ocellata* (1900, p. 226, one specimen).

Von Graff (1899, p. 356) includes in *G. graffii* all the varieties then described—i.e., *somersii, occidentalis* and *otiraensis*. I have had no specimen of the variety *somersii,* but Dendy (1900, p. 227) in describing the variety *nodosa* which is now definitely *graffii,* says: "This variety comes very near to *G. graffii* var. *somersii.*" The variety *occidentalis* is *graffii,* but specimens of *otiraensis* from Dendy's collection have been sectioned and are entirely different internally from *graffii* and should not therefore be included in that species.

One of the earliest land planarians described from Dunedin is *G. moseleyi* Hutton (1880). Unfortunately no size is given in the description, but von Graff (1899, Pl. 6, Figs. 33–35) figures the specimen now in the British Museum. Very few markings seem to have remained (judging from the figure), but from Hutton's description and the general shape and size according to the figure, it is possible that *G. moseleyi* and *G. graffii* are the same worm; Dendy (1896) says: "Perhaps in the future it may be desirable to unite the several varieties of *G. graffii* which I have described, together with *G. iris* and the Dunedin form described by Hutton (i.e., *G. moseleyi*) under the one name *G. moseleyi,* which will then have to be regarded as a widely-spread species with numerous local varieties." Dendy was right so far. Several varieties of *graffii* and *iris* (in part) have now been found to belong to one species *G. graffii.* Whether the name of that species will remain *graffii* or be changed to *moseleyi* can only be decided when the internal structure of the type *moseleyi* is known.

Artioposthia howesi (Dendy).

1900. *Geoplana howesi* Dendy, *Trans. N.Z. Inst.*, vol. xxxiii, pp. 238–239.

Locality. Numerous specimens were collected by Professor Marples at Duntroon, North Otago, New Zealand, at all times of the year. One specimen from the British Museum was found at Invercargill Bush.

External Characters. Dendy (1900, p. 238) gives the length in spirit as 24 mm., which is an average size, living specimens varying from 15 mm. to 32 mm. The dorsal surface is pale yellow, with three brown stripes and an orange anterior tip. The ventral surface is pale yellow with no markings. The three ventral longitudinal bands which Dendy describes in spirit have not been seen.

The three dorsal stripes consist of one narrow median stripe and two much broader bands, about half way between the median stripe and the margins. There is much more variety both in the form and the colour of the stripes than Dendy indicates. He gives the colour as dark brown, but actually it varies from bright tan to dark brown. Dendy also describes the stripes as solid bands of colour in which there are no speckles and none between the bands, this being one of the features which distinguish *howesi* from *G. subquadrangulata.* Actually alongside the typical *howesi* are always found some smaller forms which are generally similar to the larger ones except for the fact that the stripes of the small ones are composed of brown

speckles and are not so well-defined and solid-looking. These smaller worms have been sectioned and also examined in oil of wintergreen and are found to be immature. From the examination of a great variety of specimens at various times of the year, it would appear that the lateral stripes which in young forms are tan-coloured and are composed of speckles, gradually become darker and the speckles more numerous as the worms grow, until in the fully-grown worm the stripes are very dark brown, and the speckles have become so numerous as to run into each other and form continuous lateral bands.

The eyes are numerous and are arranged in a single row right round the anterior tip. The mouth is slightly nearer the posterior than the anterior end, and the genital pore is about half-way between the mouth and the posterior end.

Reproductive Organs. There is a common genital atrium (g.at.) into which the male duct opens anteriorly through a muscular penis (pe.), and the female duct opens posteriorly through a muscular process of similar length. From the dorsal wall of the atrium three adenodactyli project into the atrial cavity.

The paired ovaries are in the usual ventral anterior position, and from each a single oviduct goes back. Behind the atrium the two oviducts join to form a wide ovisac (os.), which gradually narrows and opens into the atrial cavity through a long muscular process. The ovisac contains sperms and mucus and receives the secretion from numerous glands on the ventral surface.

The testes lie below and slightly between the gut-diverticula, and extend from just behind the ovaries to the genital atrium. The vasa deferentia (v.d.) from each side join to form a short, narrow seminal duct (d.s.) which opens into the seminal vesicle. The seminal vesicle (v.s.) has two regions connected by a short, narrow duct. The proximal region is wide and ciliated, and contains sperms, the distal region is glandular and contains lumps of secretion and opens to the exterior by a short ejaculatory duct.

The adenodactyli (aden.) are of the usual type each with a glandular duct opening into the atrial cavity. Unlike those of *A. triangulata* (1937), there is no inner reservoir, but the duct enlarges to form a glandular cavity near the opening to the exterior.

Remarks. It is obvious that the classification of the land planarians cannot be based wholly on external markings, eyes, adhesive organs, etc., rather that it must be based primarily on the reproductive organs, though how much variation is to be allowed for seasonal changes is not clear.

The genus *Artioposthia* was created for those forms with adenodactyli, and three separate species have now been described for New Zealand. Miss Hyman (1931), however, thinks that the copulatory organs are unsuitable for classificatory purposes, and while stating that adenodactyli are absent from all American forms, doubts their taxonomic value. If adenodactyli are only a seasonal or sexual variation, then a regular examination of one species at short intervals throughout the year should help us to reach some definite conclusion

on this point. In both summer and winter, fully-grown specimens of *A. howesi* had adenodactyli, and it would appear as if they were here a definite regular part of the reproductive system. The writer is at present examining fortnightly collections of *A. triangulata* in an endeavour to decide whether adenodactyli are a constant feature of that species.

The writer records her thanks to Professor B. J. Marples for valuable suggestions and criticism.

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Vol. 74, Part III, pp. 294–296, Plate 40.

The Octopodous Mollusca of New Zealand.—V.

By William Benham, K.B.E., F.R.S.,
University of Otago, N.Z.

[*Read before the Otago Branch, May 5, 1944; received by the Editor, May 15, 1944; issued separately, December, 1944.*]

In my previous articles (*Trans. Roy. Soc. N.Z.*, vols. lxxii, lxxiii, lxxiv) I have described species of Octopods belonging to the Family Octopodidae. I now put on record as occurring in our coastal waters certain other species belonging to other families of the great Order Octopoda. Although I have nothing to add to our knowledge of this octopod my excuse for cumbering the pages of the *Transactions* is the fact that the literature and figures of *Tremoctopus* such as those of Naef are not readily available to zoologists in the Dominion, and the only figure that is available is erroneous.

Tremoctopus violaceus Della Chiaje. Plate 40, Figs. 1–3.

This widely distributed species, originally described from the Mediterranean somewhere about the year 1830, has already been recorded from our seas by Suter (1913, p. 195) who obtained a specimen from near the Great Barrier Island; this was identified by Hoyle, who had worked on the Cephalopoda collected by H.M.S. *Challenger*. I have endeavoured to trace this specimen, but the directors of the museums consulted have not been able to find it in their respective collections in Auckland, Wellington, Christchurch or Wanganui.

The figure, purporting to represent this animal, given by Suter (Pl. 30, Fig. 4) is not only misleading but erroneous in some respects. For example the *web* or umbrella is represented as being produced into long points *between* the arms 1 and 2 on each side, whereas it is at these places that it is shallower than it is at the ends of the arms. I therefore give a drawing of the specimen examined by me. It is true that a good though small figure is given by Naef (Fig. 142, p. 741). But Suter was not the first to record the occurrence of *Tremoctopus*, for T. W. Kirk mentions it in 1883 where, before the Wellington Branch, he gave an abstract of a paper entitled "*On a New Cuttle-fish, Tremoctopus robinsonianus*" which in the next line he refers to as *T. robsoni*, of which he had received three individuals from Napier, two of which were males. But beyond mentioning the colour he gives no details. It was no doubt *T. violaceus*. At any rate the specific name given by him does not stand. He named it after Mr. C. H. Robson, of Mahia, who supplied him with other cephalopods.

The genus *Tremoctopus* belongs to the family Tremoctopidae, which is closely related to the Paper Nautilus, *Argonauta;* indeed by some zoologists—e.g., Suter, the genus is placed in the same family. But from *Argonauta* it differs not only in the fact that the female does not produce an external shell for the transport and protection of her eggs, but, secondly, in the possession of circular pores or aper-

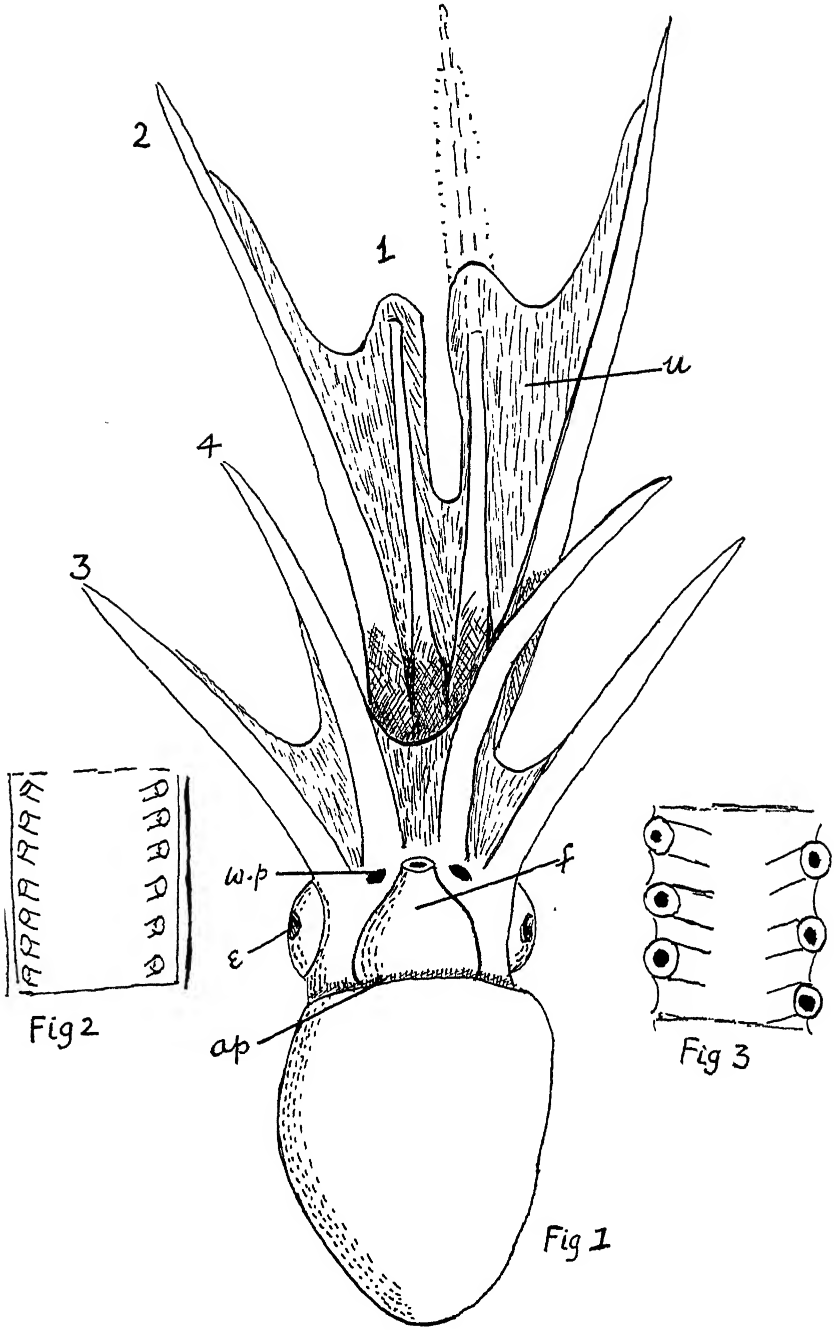

FIG. 1.—*Tremoctopus violaceus* Della Chiaje. Ventral view to show the characteristic features. The arms are numbered 1, 2, 3, 4, but the suckers are omitted; e, eye; f, funnel; ap., mantle aperture; wp., ventral water pores; u, umbrella or web. The dotted extension of arm 1 indicates the relative length of this arm in the young, but this region degenerates as the animal grows.

FIG. 2.—The arrangement of the suckers on Arm 2 (enlarged).

FIG. 3.—The arrangement of the suckers on Arms 3 and 4 (enlarged).

tures (Gk. *tremata*) at the base of the web both dorsally and ventrally which lead into chambers in the head.

The specimen hereunder described I owe to the courtesy of Dr. Oliver, who entrusted it to me for confirmation of his identification. In his letter he writes: " It was found floating in the sea at Crater Bay, White Island, on December 6, 1912. Apparently it had been killed by the water discharged from the Crater lake, which contains 5% of hydrochloric acid."

The animal is a female. The body ovoid, widest at about the middle and bluntly pointed at the hinder end (Fig. 1). The colour after preservation in formalin for 30 years is still purplish-brown dorsally, which colour is continued on the arms and web (umbrella); the ventral surface is of a paler tone, as is the colour of the inner surface of the arms and web.

The length of the body from the apex to the level of the eyes is 75 mm., and its greatest breadth is 55 mm. This is about the average size of the species. The surface is smooth. The mantle aperture is wide (Robson's "C "). The arms formula is 2:1:4:3, though the last two are almost equal in length. A peculiarity about the pair of the most dorsal arms (No. 1) is, as has been described by Naef (p. 740, Figs. 442, 443), that during the growth of the animal each of these two arms loses more or less of its distal region by a sort of degeneration. When newly hatched and for some little time after, these two dorsal arms are longer than the second arms (2), but as the animal grows the distal portion slowly rots away. From Naef's article it appears that the reason of this peculiarity is quite unknown, and no explanation has been suggested. In the present individual the length of the second pair (No. 2) is 175 mm., measured as usual from the mouth, hence the total length of the animal is 250 mm., about 10 inches. The dorsal arms (No. 1) are only 150 mm. though one is rather shorter than the other.

The inner surfaces of the arms present different appearances. On the two pairs of dorsal arms (Nos. 1 and 2) the suckers are quite small, except those quite close to the mouth, and are arranged along the edge of the inner face so that the two rows are wide apart and separated by a flat, smooth area (Fig. 2) which in arm 1 is 3 mm. wide and in arm 2 as much as 7 mm. (Naef figures them on p. 741, Fig. 442). In the other arms (3 and 4) the suckers are arranged as usual, as short cylinders of large size arranged close together, as in the genus *Octopus*, and the space between the two rows is quite narrow (Fig. 3).

I do not recall reading of such an arrangement in ordinary Octopods though it is not unusual for the suckers to differ in size in different arms.

The web, or umbrella, has quite an unusual and therefore a characteristic arrangement. It is highest between the arms 1 and 2, passing up the side of the latter almost to its tip. Between the pair of dorsal arms (No. 1) it is very much shallower, though it passes up the mesial side of the arms as far as the fractured ends and even beyond. The other sectors are about half this height. The different

sectors have the following heights (measured from the mouth to the edge), using Robson's nomenclature:—

A. 70 mm.
B. 125 mm.
C. 35 mm.
D. 30 mm.
E. 30 mm.

A peculiarity already referred to, in which the genus differs from the rest, is the existence of two pairs of "water-pores" as they are termed. These are small, circular perforations of the web close to the roots of certain of the arms (Fig. 1, wp.). One pair is dorsal, close to the roots of arm 2, the other pair ventral, close to arm 4. Each pore leads into a semicircular chamber or head-cavity, one therefore on each side of the head which thus opens both dorsally and ventrally. This cavity passes between the eye and the base of the arm, and sends outgrowths or sacculi between the roots of the arms, and one such sacculus runs above and behind the eye, and still another ventrally between the eye and funnel (I have summarised Naef's account). The function of this series of channels and chambers seems to be unknown. A single pair of "water-pores" occurs on the ventral surface of the head of *Ocythoe*, and their occurrence here led one author at least (Pelseneer) to group the two genera in a Family Philonexidae. But more modern zoologists place the genus *Tremoctopus* in a separate Family Tremoctopodidae, of which it is the sole genus. It is sometimes called a "pelagic argonaut" as it is without an external shell and by some authors it has been relegated to the Family Argonautidae.

The species *T. violaceus* is widely distributed, having been recorded from the Mediterranean, the Atlantic, the Red Sea and the Pacific. In addition to those that have been found on the coasts of New Zealand at Napier, the Great Barrier and Crater Island, Massy (1916) obtained a few very young ones (4 and 5 mm. in length) off the Three Kings Islands during the expedition of the Terra Nova, in 1910.

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The Anatomy of the Final Larval Instar of *Diadromus (Thyraeella) collaris* Grav. (Ichneumonidae), with Notes on Structural Changes Through the Prepupal and Pupal Stages.

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[*Read before the Nelson Branch, July 17, 1944; received by the Editor, August 4, 1944; issued separately, December, 1944.*]

INTRODUCTION.

Three larval instars are present in the life-cycle of *Diadromus,* and in appearance these stages are all similar in their maggot-like form. However, it is in the third instar and the prepupal stages that most of the transition from larval to adult organisation is noted, and consequently it is these stages which have been selected for special study. Although the pre-adult stages do not differ markedly from those of other ichneumons, there are certain features, such as the heart development, and the lack of complete histolysis, which are worthy of note. In the present account, only the more noteworthy features are dealt with.

THE THIRD INSTAR LARVA.

Immediately after ecdysis, the third instar measures approximately 2·5 mm. in length, but by the time feeding is complete, this dimension may reach as much as 4·5 mm. During this instar, considerable changes occur, and in the prepupal phases, adult structures can be clearly seen in an advanced stage of development. The spiracles are open throughout the instar, and the tracheal system functions normally. Abdominal chaetotaxy is lacking, and there is increased development of sensillae and sensitive apparatus generally in the oral region. Although the following anatomical description applies particularly to the active third instar, it also applies in its fundamentals to the earlier stages.

Head-capsule. (Figs. 1 and 2.)

The head-capsule in general outline from dorsal, lateral, or ventral aspects is approximately hemispherical in general form, although slightly flattened ventrally. The maxillary lobes (ma.) are rather less prominent, while the labium (lb.) is more prominent than in the earlier instars.

The labium is in the form of a hemispherical papilla which is constantly retracted and everted during feeding. The clypeal arch (cla.) bears on its ventral margin, a definite plate-like, lightly-chitinised flange (clp.), bearing several placoid sensillae. The labrum (lbr.) also has several sensillae with broad placoid bases, but each bears a minute central spine. From the inner side of each lateral arm of the clypeal arch, is an inwardly projecting chitinous process to which pharyngeal muscles are apparently attached. The pleurostomal

arches (pl.) and the mandibular struts (sms. and ims.) are much more strongly developed than in the earlier instars, but show no essential structural improvement. The mandibles (md.) are essentially the same as in earlier instars, but the articulation is better developed, and the mandibular apices are more tapering.

On the maxillary lobes and labium, definite palpal rudiments are seen in the form of complex chitinous discs containing sensory pits. Scattered basiconic and placoid sensillae occur on these organs and on the nearby cuticle. Above the clypeal arch are two lateral clusters of strong basiconic sensillae, but no definite antennary rudiments are to be seen.

Nervous System. (Figs. 3, 5, 6, 7.)

The nervous system is of a very primitive type, consisting of a comparatively unspecialised double chain of ganglia, connected by longitudinal and transverse commissures.

The largest ganglia are the supraoesophageals (sog.), which are ovoid, lying above the oesophagus just in front of the mid-gut. These ganglia give off definite trunks (mdnv.) to the anterior part of the head above the mouth. The paraoesophageal commissures run each side of the oesophagus to the suboesophageal ganglia (sug.), which give off trunks to the maxillae and labium (lb.nv.).

Behind this are the three pairs of thoracic ganglia fairly close together, and ten pairs of abdominal ganglia. No definite nerves are present behind the cephalic region.

Digestive System. (Figs. 3, 5, 6, 7.)

The digestive system is peculiarly degenerate in several ways due to the peculiar mode of life of the larva.

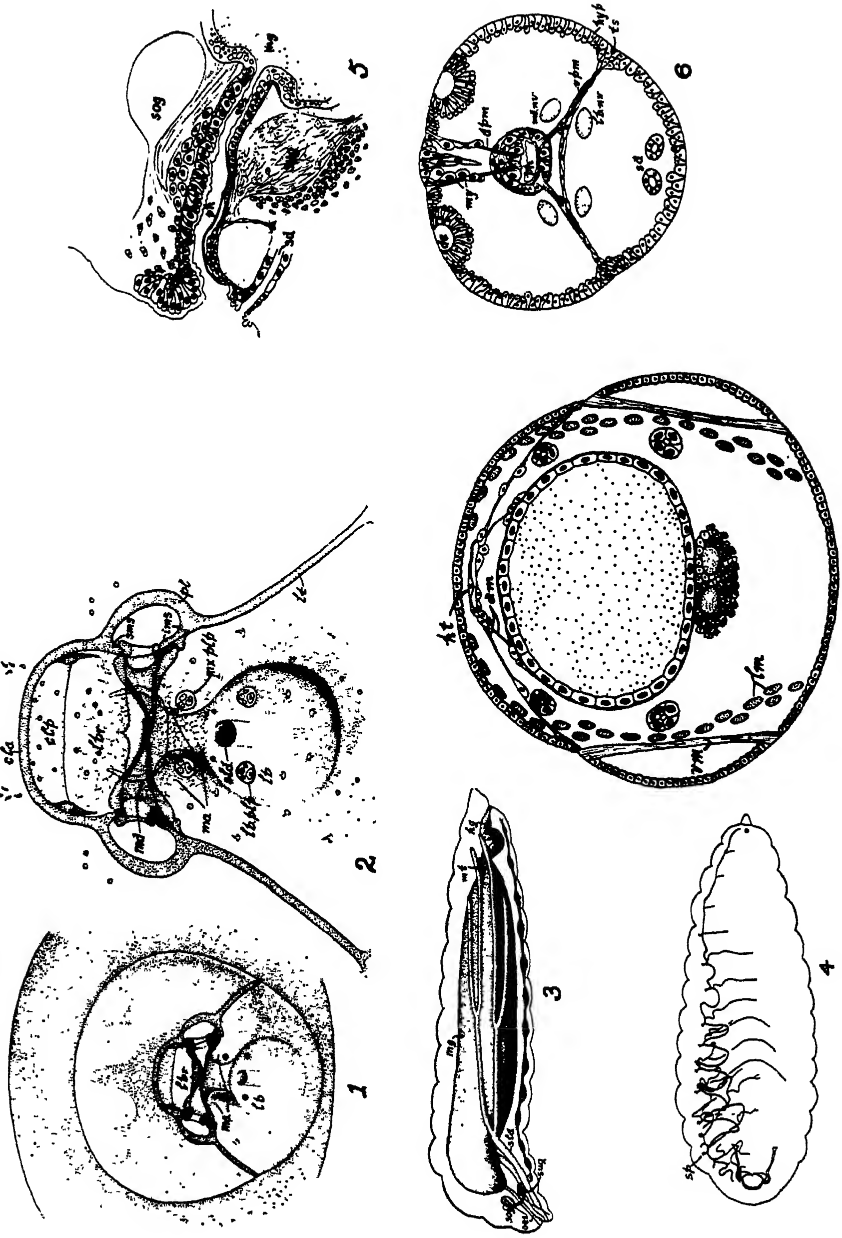
The oesophagus (oes.) is a short straight tube leading from the buccal cavity to the relatively enormous sacular mid-gut (mg.). The lining of the oesophagus consists of rather irregular cubical and columnar epithelium, underlain by a very poorly-developed muscular layer. The pharyngeal portion (ph.), which is separated from the oesophagus only by the presence of a thicker chitinous lining on its floor, has an arrangement of paired dorsal and ventral muscles extending outwards to the body-wall (dpm. and vpm.).

The mid-gut is lined with somewhat flattened cubical epithelium, and appears to be a storage organ for all material passing through the mouth. Here again, the muscular layers are very feebly developed. This storage organ occupies the greater part of the abdominal cavity, and leads behind to the blind hind-gut (hg.).

The malpighian tubules (mt.) are degenerate, being represented merely by paired, solid papillae. The hind-gut is not functional and consists of a more or less solid mass of cells. This hind-gut becomes functional only when the final prepupal ecdysis is about to take place. At this period, all the faecal matter accumulated and stored in the gut during the larval life is excreted.

Salivary Glands. (Figs. 3, 5, 6, 7.)

The salivary glands (sd.) are very well developed, and are one of the most conspicuous anatomical features of the larva. These glands open to the exterior on the dorsal surface of the labium, and the



Diadromus (*Thyraeella*) *collaris* Grav.

Fig. 1.—Head Capsule. Front view.
Fig. 2.—Mouth parts and tentorial apparatus.
Fig. 3.—Longitudinal vertical steriosection of entire larva.
Fig. 4.—Trachial trunks. Ventral.
Fig. 5.—Pharynx, etc. Longitudinal vertical section in situ.
Fig. 6.—Transverse section through pharyngeal region.
Fig. 7.—Median transverse section of entire larva.

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opening is held in shape by a distinct chitinous collar. The duct bifurcates at the base of the labium, and the two branches run one on each side of the body to the base of the mid-gut at the posterior thoracic region, where each duct bifurcates again. About half way from the anterior to the posterior extremity, the third and final bifurcation occurs. Of the four branches now running along each side of the gut, the middle two are the longest, reaching to the beginning of the final abdominal segment.

These glands are straight and simple. They are glandular throughout their length, and are evidently very active. The cells are very large, with relatively huge nuclei. The cytoplasm appears granular-reticulate in section, and is very dense.

Respiratory System. (Fig. 4.)

In the third instar, the respiratory system is well developed and very complex. Spiracles (sp.) open to the exterior in the groove ventral to the pleural ridge on the first nine body segments. These spiracles are lagenate in shape, with necks leading to the main lateral tracheal trunks. The lateral trunks follow a sinuous course, forming ventral loops, particularly in the anterior five body segments. The first three thoracic loops are connected basally by stout sinuous commissural trunks.

Most of the subsidiary branches originate near the spiracular necks. From the first two thoracic spiracles, no ventral or dorsal commissures arise, but from the metathoracic and first two abdominal spiracles, originate complete ventral commissures. These commissures are incomplete in following segments, and their development progressively decreases posteriorly. From the main trunks, numerous finer tracheae arise which supply the tissues of the body.

In the early instars particularly, there is an extremely diffuse supply of hypodermal tracheae and tracheoles. Apparently this network serves a purpose in the absorption of oxygen from the surrounding body-fluids of the host.

Vascular System. (Fig. 7.)

Although the writer has been unable to locate any definite heart in the first instar, in the second instar it is present, and in the third well developed, and resembles the adult heart in structure. It is in the form of a dorso-ventrally flattened tube extending almost the entire length of the body of the larva. Dorsally it is suspended from the body-wall by cellular pillars (not illustrated), and ventro-lateral alary muscles are present. These alary muscles arise from groups of cells at the lateral edges of the heart, and extend outwards to the top of the pleural ridge. There are also irregularly-placed, very fine fibres inserted in the wall of the mid-gut.

In the fat-body, large, rounded oenocytes occur, and throughout the body various types of leucocytes are present.

Excretory System and Fat-body.

The malpighian tubules are not functional, and all excretory products are stored until the final prepupal ecdysis or later. Dorsally, there are metamerically arranged groups of relatively huge urate cells in the fat-body. These clusters can be seen in the living fully-

fed larva as white opalescent clusters beneath the dorsal body-wall. Whether or not any nitrogenous secretions are passed out with the gut-contents during the final prepupal ecdysis is not known, but these clusters of urate cells are still present during the pupal stage, and apparently their urate contents are not removed until the adult malpighian tubules are completely developed.

The fat-body cells are very large, and are almost identical with those of the adult. However, the peripheral layer of smaller cells is wanting in the larva.

The Prepupal Stages.

The stages in prepupation as described here are based on the work of K. Morris (1937).

When fully fed, the larva is more or less cylindrical in form, with the three thoracic segments, particularly that of the mesothorax, rather broader dorsally than the abdominal segments. This dorsal broadening gives the larva a rather hump-backed appearance, and forces the head downwards. Antero-posterior compression of these thoracic segments now begins, and this development marks the beginning of the prepupal stages. This slightly compressed form is known as the eonymph. The characteristic changes to produce the second stage or pronymph, consist of a marked dorsal enlargement of the abdominal segments, and the production of a slight "waist" between thorax and abdomen. At the same time the head becomes deeply sunken into the prothoracic segment, and the pleural ridge becomes less prominent. By this time, the imaginal eyes can be clearly seen, due to deposition of red pigment.

During the prepupal period, most of the elaboration of imaginal organs takes place. The imaginal discs for the antennae, wings, and legs, can be seen even in the first instar larva, but it is not until the prepupal stage that these structures begin conspicuous development. True histolysis is not apparent in *Diadromus,* and through the prepupal stages, a gradual absorption of larval structures, and the gradual building-up of adult organs takes place.

The larval gut degenerates rapidly, and becomes filled with a solid core of large, dense cells. By gradual arrangement and differentiation, the adult gut forms from this core of cells. During the prepupal period, all nervous elements are likewise gradually elaborated, and at no time is a central nervous system lacking in a recognisable form. The adult heart appears to develop by direct modification of the corresponding larval structure, and at this stage, both adult and larval muscles may be seen at the same time, one being built up from undifferentiated cell masses, the other being absorbed.

The genital structures probably become more or less differentiated at this stage, but the writer has been unable to detect them until fairly late in the pupal stage. One of the last of the larval structures to disappear are the salivary glands. The abdominal branches of these glands can still be seen in fairly late pupal stages, when the cephalic and thoracic organisation is almost completely imaginal.

The Pupal Stage.

After the comparatively long prepupal stages, the pupa libera emerges. By this time the adult organisation is well advanced, although the only pigmented portions of the insect are the compound eyes and ocelli, which are bright red. Very soon, the thorax becomes pigmented, but it is not until shortly before emergence that abdominal pigmentation occurs. Development is much more rapid in the cephalic and thoracic regions than in the abdominal region.

The protection of the pupa, it will be noted, is afforded entirely by the pupal skin and cocoon of the host. There is not the slightest indication of cocoon development or corresponding modification of the salivary glands in the parasite larva.

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KEY TO LETTERING OF FIGURES.

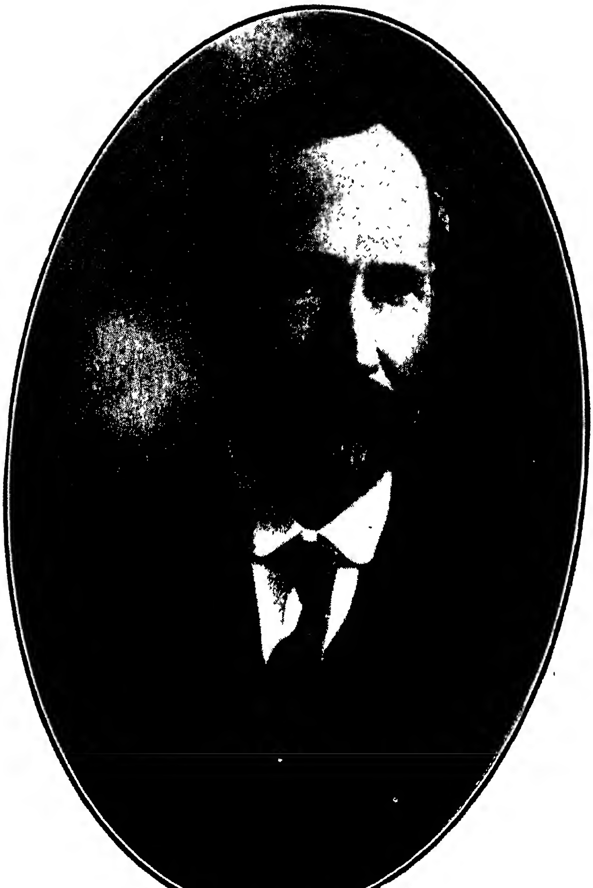
am.—alary muscle.
cla.—clypeal arch.
clp.—clypeal plate.
de.—developing imaginal eye.
dpm.—dorsal pharyngeal muscle.
hg.—hind-gut.
ht.—heart.
hyp.—hypodermis.
ims.—inferior mandibular strut.
lb.—labium.
lbnv.—labial nerve.
lbr.—labrum.
lm.—longitudinal muscle.
lp.—labial palp.
lt.—lateral tentorial arm.
ma.—maxillary lobe.
md.—mandible.
mdnv.—mandibular nerve.
mg.—mid-gut.
mp.—maxillary palp.
mt.—malpighian tubule.
my.—myelocyte.
oes.—oesophagus.
ph.—pharynx.
pl.—pleurostoma.
sld.—salivary duct and gland.
sms.—superior mandibular strut.
sog.—supra-oesophageal ganglion.
sug.—sub-oesophageal ganglion.
sp.—spiracle.
ts.—tentorial strut.
vm.—vertical muscle.
vpm.—ventral pharyngeal muscle.

OBITUARY.

Frederick Chapman, Hon. F.R.S.N.Z.

F. Chapman, A.L.S., Hon. F.R.M.S., F.G.S., was born in 1864, and died in Melbourne on December 10, 1943, leaving his son, Brigadier W. D. Chapman, and a grandson, both of the A.I.F., carrying out in their several spheres their ideals of public service. He was the son of Robert Chapman, assistant to Professors Faraday and Tyndall, and at the age of 18 was appointed assistant to Professor J. W. Judd, at the Royal School of Mines. His life-long interest in micro-fossils was expressed by his first paper on the foraminifera and ostracods of the London Clays below Piccadilly, published in 1886, which was followed by a series of papers during the decade 1890–9 dealing with the foraminifera of the Lower Cretaceous (Gault) of Folkestone, which was practically the first comprehensive work to show the significance of these small organisms for stratigraphical zoning, a study which has since proved of immense importance, and now, carried on in countless laboratories throughout the world, guides the geological investigation of oilfields. His textbook on the foraminifera, the only work of its kind until 1928, appeared in 1902, in which year he was appointed palaeontologist to the National Museum, Melbourne. Here, as one of the very few Australian palaeontologists, he was called upon to study fossils of all kinds, his first task being to name and arrange the large and now well-displayed collections of Australian and foreign fossils in the National Museum. A quick succession of papers came from his pen, and at his death his bibliography included 500 titles, so that he and the late Robert Etheridge, jun., have the distinction of being the chief contributors to Australian palaeontology. Foraminifera form the subject of many of his papers, his opinion being sought in many countries outside Australia. Notable among his foraminiferal papers are those dealing with the collections of the Shackleton and Mawson Antarctic Expeditions, studies of South African material and of the foraminifera in the collections of the New Zealand Geological Survey, which he described in Palaeontological Bulletin No. 11 (1926) having completed earlier for the same Survey a Palaeontological Bulletin (No. 7, 1918) on the fossil fishes. His election to the Honorary Fellowship of the Royal Society of New Zealand, in 1932, was an appropriate acknowledgment of this and other contributions to New Zealand palaeontology. Similar comprehensive studies of fossil foraminifera from the Cainozoic formations of Australia have been of great service in the elucidation of its geological history. A long series of papers under the title of "New or Little Known Fossils in the National Museum" records many other and very varied features of past life in Australia.

Retiring from the service of the National Museum in 1927, he continued till 1936 working in his old laboratory as Commonwealth Palaeontologist, guiding by his studies the search for oil in Western



F. Chapman

Hon. F.R.S., N.Z.

Obiit, December 10, 1943.

Australia, New Guinea and Victoria, and teaching in Melbourne University, to which he had been appointed as part-time lecturer on Palaeontology in 1920.

Though quiet and unassuming, he took an active part in the scientific life of Melbourne, was President of the Royal Society of Victoria, the Microscopical Society and the Field Naturalists' Club, and contributed by several semi-popular books, many newspaper articles and broadcast talks to the furtherance of public interest in natural science. His enthusiasm for the cultivation of native plants was shown both by his own garden and by the Maranoa Native Plant Garden, of which he was Honorary Curator.

It is impossible for one man to be a complete expert on fossils of all types and ages, and naturally some of his conclusions have since been modified by specialists in one or other of the many groups of organisms which he studied. But as an Australian-trained geologist, the writer desires to pay tribute to the immense value of Chapman's promptly completed work to the steady advance of geology in all parts of the Commonwealth, notably his study of the Silurian and especially Cainozoic fossils, appropriately recognised by the award to him of the Lyell Medal of the Geological Society of London, in 1930.

A last personal association with Mr. Chapman was at a laboratory party in the National Museum in honour of his seventieth birthday, during which it was revealed, though not by the guest, that his form of celebration had been by making a gift to enable the young folk in a children's home to share his enjoyment and interest in the many aspects of life to be seen on the hills and beaches near Melbourne—very characteristic of a most kindly and lovable naturalist.

W. N. B.

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Protozoa From New Zealand Termites.

By Frances R. Nurse, M.Sc.,
Canterbury University College, Christchurch.

[*Read before the Canterbury Branch, May 3, 1944; received by the Editor, September 1, 1944; issued separately, March, 1945.*]

Introduction.

The intestinal fauna of the termites of New Zealand has not up to date been dealt with fully. Helson (1935) described a new protozoon belonging to the order Hypermastigina, *Spirotrichosoma magna* from *Stolotermes ruficeps* Brauer. There are two termites endemic to New Zealand, *Stolotermes ruficeps* and *Calotermes brouni.* Helson did not state a locality for his material, but there is reason to believe that it was obtained from Westland. Material for this paper was collected from Banks Peninsula, where both *S. ruficeps* and *C. brouni* were present in *Podocarpus totara* and *P. spicata* and one colony of *S. ruficeps* was recorded from *Griselinia littoralis;* also both genera were collected in the Nelson district; *C. brouni* from *Laurelia novae zelandia* and from the weather boards of an old farmhouse where it had caused considerable damage, and *S. ruficeps* from *Metrosideros lucida.* Material of each genus was often collected from adjacent logs and indeed, in one case, both from one log where the sampled areas were 20in apart. In every case each genus had its characteristic fauna and no intermingling of the protozoa was found, in fact an attempt to cause the fauna of the two genera to intermingle was unsuccessful in the laboratory. *S. ruficeps* was also obtained from the Teremakau Valley, Westland.

The flagellates described are Polymastigotes belonging to the families Devescovenidae, Oxymonadidae, Joenididae and Trichomonadidae.

Material and Technique.

Studies on living material were made by diluting the contents of the gut in either 0·75% saline or Ringer's solution. The large flagellates kept their shape for a much longer period in saline, which was most useful for a general study. On the other hand, in Ringer's solution the protoplasm tended to disintegrate after half an hour, leaving the neuromotor system intact, which was then more easily studied. The three small flagellates behaved equally well in both solutions.

Fixatives used were: Schaudinn's without acetic, Bouin's, Flemming's without acetic, Zenker's and Osmic vapour. Mallory's triple, Heidenhain's iron-alum haemotoxylin, Delafield's haemotoxylin and Erhlich's triple stains were used. Eosin or acid fuchsin was used as counter-stain for Heidenhain's iron-alum. Neutral red and methylene blue were used as intra vitam stains while alcoholic iodine served for emphasising flagella.

The best results in general observation were obtained with living material. A trace of alcoholic iodine in the saline or Ringer's solution rendered the flagellate clear and transparent so that the internal structures were clearly visible.

The best preparations were obtained from material fixed in Schaudinn's or Zenker's and followed by Mallory's triple stain, and Osmic vapour followed by Heidenhain's iron-alum haemotoxylin counter-stained with acid-fuchsin or eosin. Erhlich's Triple stain picked out particularly wood particles and the nucleus.

Caduceia calotermidis n.sp.

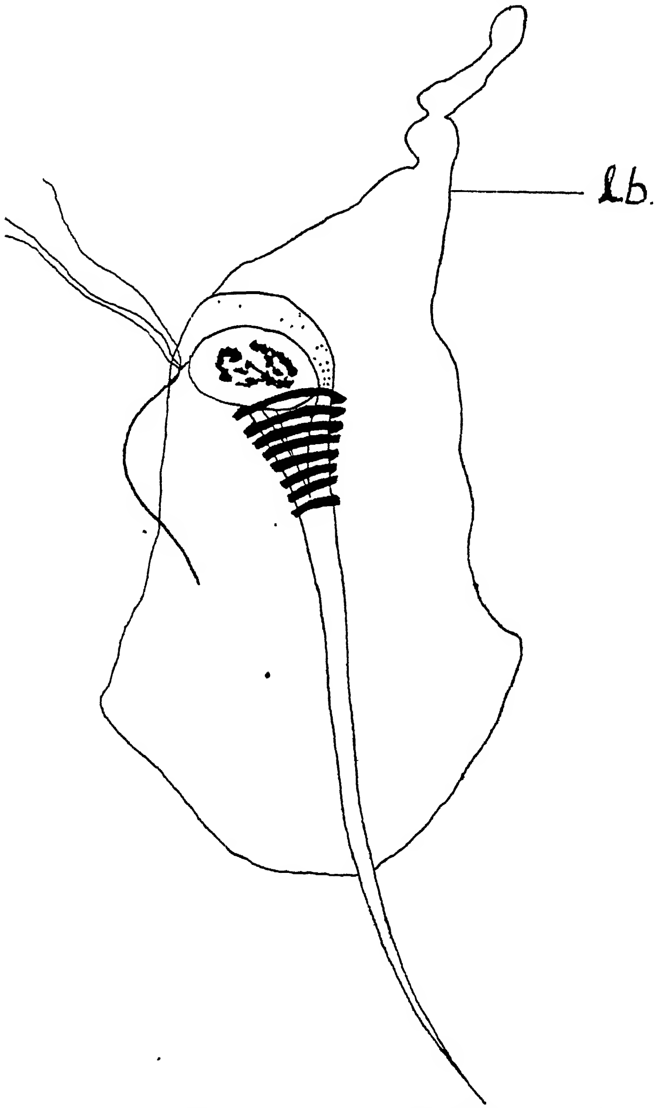
Host: Calotermes brouni.

Diagnosis: Length, 56μ–84μ; width, 33·6μ–47μ; three anterior flagella; trailing flagellum slender cord, less than body length; no cresta visible; parabasal body single spiral 5–11 coils (mostly 7 or 8 coils), fairly tight; capitulum of axostyle with granules (chromatic shield); nucleus 10·7μ x 7·6μ in large forms; rod-shaped micro-organisms adherent to parts of surface; spirochaetes 4μ–6μ long forming a dense coat over most of surface.

In the unstained living condition the flagellate is clear, the structures and wood particles within the cytoplasm being quite visible. The shape of the body is generally ovoid or pyriform, but it is also capable of changing. There is an axostyle present which projects posteriorly, sometimes to the length of 33·6μ. The size varies from 56μ–84μ long and 33·6μ–47·6μ wide. The anterior end is rounded on one side and prolonged into a snout on the other, from which three flagella of equal length project (Pl. 42, Figs. 2 and 3). There is a fourth trailing flagellum, a little stouter than the other three, which arises from the same place and projects backwards. It is about half the length of the body. The anterior portion, which has the appearance of a "head" with a projecting snout, is highly mobile, and at the same time the anterior flagella are lashed about in unison towards and away from the body. The fourth, trailing flagellum is vibrated actively and continuously. Nearly the whole of the organism is invested with spirillum-like bacteria 4μ–6μ in length (Pl. 42, Fig. 1) like those which have been called spirochaetes by Dobell (1910) and Damon (1926). Janicki, quoted by Kirby in his description of *Devescovina striata* var. *hawiensis*, mentions the spirillum-like bacteria investing the surface. Similarly, Kirby on *D. lemniscata* (1926) and Light (1926) on *Metadevescovina debilis* mention the bacteria adhering to the surface.

These spirochaetes were not removed by a weak tincture of iodine in 70% alcohol (Light, 1926), but were only removed after feeding on filter paper soaked in ·5% acid Fuchsin for a month (Cleveland, 1928). After this treatment the surface of the protozoa was quite free from spirillum-like organisms but there were also rod-like structures arranged in groups on the surface (Pl. 42, Fig. 1), which gave the appearance of striations. These were seen to swim off, then attach themselves again, and were obviously separate organisms. When invested with spirochaetes the flagellates moved along smoothly and vigorously, sometimes revolving on the longitudinal axis. The spirochaetes were directed posteriorly and appeared to be beating uniformly. When divested of its spirochaetes, the organism barely moved. The movement which took place seemed to be due to changes in shape of the body and the movement of the mobile head region with the flagella. Some of the flagellates were seen to send out extremely active lobopodia from the anterior end

(Text Fig. 1, lb.) and at the same time the cytoplasm underwent rapid shimmering movement. With the movement of the mobile "head" region the parabasal body and axostyle were turned also.



TEXT FIG. 1.—Living specimen of *Caduceia calotermidis* n.sp. from which the spirochaetes have been removed by acid fuchsin.

The movement of *C. calotermidis* when covered with spirochaetes corresponds exactly with Kirby's description of *Pseudodevescovina uniflagellata* (1936, pp. 313–314). He draws attention to the vigorous movement of the animal, which far surpasses *Stephanonympha,* an animal completely covered with flagella, and yet *P. uniflagellata* possesses such an apparently feeble locomotor apparatus. It is similar

to *C. calotermidis,* possessing the anterior flagella and a slightly stouter trailing flagellum which, he states, could hardly be responsible for the rapid motion. In the light of the feeble locomotion of *C. calotermidis* when naked as compared with the rapid and vigorous movement when covered with spirochaetes, it is suggested that they play a part in locomotion.

The axostyle, which is clearly visible, is a hyaline flexible rod which runs from the anterior end, just behind the mobile portion, to the posterior end from which it projects variously. The anterior portion of the axostyle is tri-radiate and situated part way in this inverted tetrahedron is the nucleus (Pl. 42, Fig.2). The nucleus is scarcely visible in life, but can be seen as a greyish ovoid body. The axostyle appears to continue anteriorly over one side of the nucleus and goes to form part of the head region. This continuation of the axostyle is called the capitulum (Pl. 42, Figs. 2 and 3 cp.) by Kirby (1936). This region is granular, and the granulation continues over one side of the nucleus into the region lying between the three rays of the axostyle (Pl. 42, Figs. 2, 3 and 4). From the base of the tri-radiate portion, the axostyle (though nearly cylindrical in this region) tapers to a point posteriorly.

Wrapped around the anterior portion of the axostyle is the clearly visible parabasal body in the form of a spiral in a counter-clockwise direction which is wide anteriorly and tapers posteriorly (Pl. 42, Figs. 2, 3 and 4). The band of the spiral is wide, being $\cdot 7\mu$, and there are up to 11 turns in some specimens, most having 7 or 8. Anteriorly the spiral continues as a fine thread to the point from which the four flagella arise (Pl. 42, Figs. 2 and 3).

The cytoplasm round about the axostyle, from the spiral backwards is dense and contains wood particles and food vacuoles (Pl. 42, Fig. 2). One food vacuole was observed to have living bacteria and spirochaetes in it. There is a fairly wide margin of clear ectoplasm. On bursting, the cytoplasm flows away leaving the neuromotor apparatus intact (Pl. 42, Figs. 3 and 4). This consists of the axostyle with its capitulum continued to form the snout, the nucleus, parabasal body and the four flagella.

In fixed material the shape of the organism is variable but in most cases the anterior and posterior ends appear blunter than in life, also the organism becomes more spherical than ovoid. The axostyle shows more structure; there is a central striated core (Pl. 42, Figs. 3 and 4) which stains pale mauve with Mallory's Triple stain and grey with Heidenhain's iron-alum. Surrounding the core is an almost colourless sheath (Pl. 42, Figs. 3 and 4) which continues anteriorly over one side of the nucleus as the capitulum. The granules mentioned earlier in the living material stain bright red with Mallory's Triple stain after Zenker's or Schaudinn's fixative, but dark grey with Heidenhain's iron-alum. These granules resemble those described by Kirby (1936) in *C. nova*, which, according to him, probably correspond to the chromatic shield of other species.

The blepharoplast (Pl. 42, Fig. 3, blp.) shows up clearly as a dark granule (red with Mallory's Triple) at the base of the flagella. In some cases there appear to be two granules close together. The parabasal body stains readily and the parabasal thread can be seen

clearly, continuing to the blepharoplast (Pl. 42, Fig. 3).

The nucleus (Pl. 42, Figs. 3 and 4) is ovoid, being $10 \cdot 7\mu$ x $7 \cdot 6\mu$ in the larger specimens. After fixation the chromatin tends to become massed in the centre, leaving a clear space between it and the nuclear membrane. There is a karyosome present which is placed excentrically and surrounded by a clear area or halo (Pl. 42, Fig. 3). It stains bright red with Mallory's Triple, but black with Heidenhain's.

Discussion.

The genus *Caduceia*, belonging to the family Devescovenidae, was established by Franca in 1918 (*C. theobromae*). This species was redescribed by Grassé (1937) and Kirby (1938). In this paper Kirby draws attention to the similarity of the genera *Devescovina* and *Caduceia*, pointing out that the structural differences are in degree rather than kind. Nevertheless, these marked differences justify generic distinction.

According to the diagnosis of the genus *Caduceia* (Kirby, 1938, p. 2), the flagellate described above is included in this genus. Like *C. theobromae*, it resembles *Pseudo-devescovina uniflagellata* in its movements, size and shape, length of flagella and structure of trailing flagellum (slender and relatively short in *Caduceia* but flattened ribbon-like and long in *Devescovina*). Also the parabasal body is similar to that described for the genus *Caduceia*, with the parabasal thread attached to the blepharoplast.

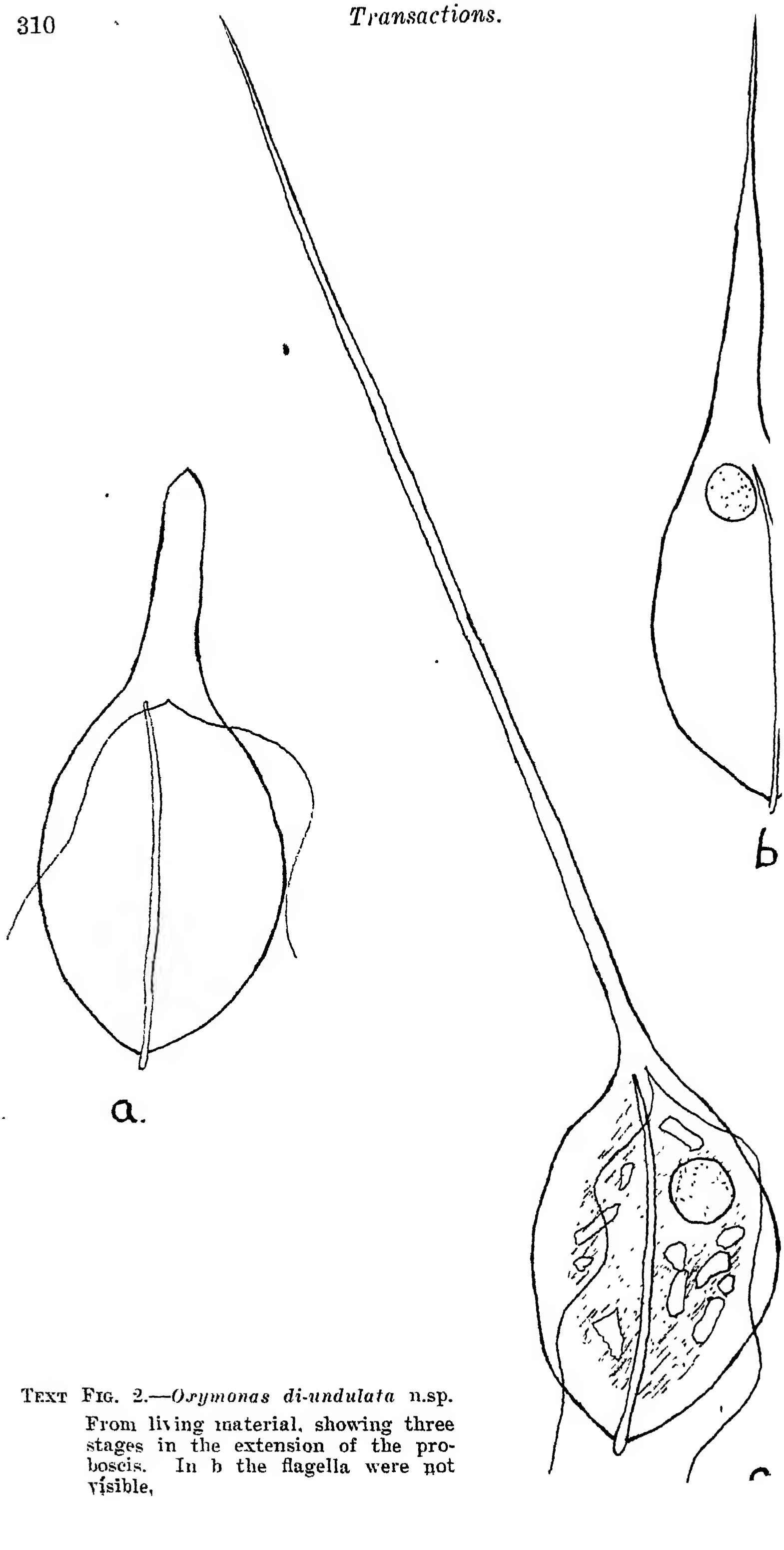
C. calotermidis resembles *C. nova* (Kirby, 1936) in the structure of the capitulum with the granules but differs in the tri-radiate structure of the anterior end of the axostyle, also in the absence of a cresta.

Oxymonas di-undulata, n.sp.

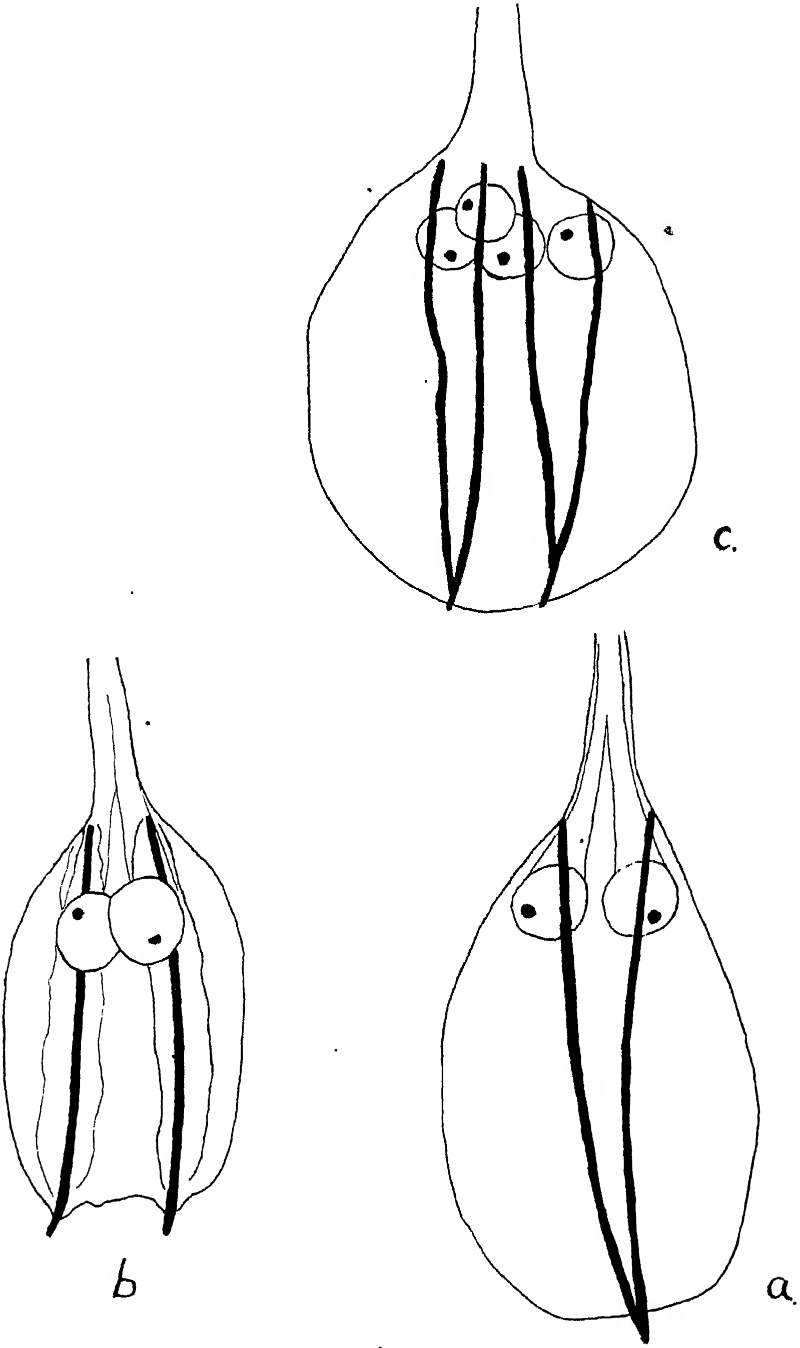
Host: Calotermes brouni.

Diagnosis: Length, $15 \cdot 3\mu$–$38 \cdot 2\mu$; width, $12 \cdot 2\mu$–$27 \cdot 5\mu$; body ovoid; nucleus anterior, spherical $5 \cdot 6\mu$–6μ in diameter; two undulating membranes each with a flagellum arising from a single blepharoplast placed anteriorly; length of flagella variable, sometimes little longer than body, mostly shorter; axostyle which projects slightly from posterior end; extensile proboscis, when fully extended up to $180 \cdot 5\mu$; proboscis when partly extended may have form of blunt cone; no proboscis sleeve visible.

The flagellate is ovoid, with an extensile proboscis which when extended is as much as nearly five times the length of the organism (Text Fig. 2c). In its retracted state this end, the anterior, is in the form of a blunt cone (Text Fig. 2a). The nucleus lies at the anterior end. There is a clear rod present which runs from the anterior end and projects slightly from the posterior. The cytoplasm is densely packed with wood particles. The size varies from $15 \cdot 3\mu$ to $38 \cdot 2\mu$ long and $12 \cdot 2\mu$ to $27 \cdot 5\mu$ wide, while the extended proboscis is up to $180 \cdot 5\mu$ long in large forms. There are two undulating membranes present, each bearing a flagellum. Each undulating membrane extends from the blepharoplast as much as three-quarters the length of the body (Pl. 43, Fig. 5). The pairs of flagella vary in length from one individual to another. The flagellates remained stationary but were seen to retract the proboscis. Some were observed to have adherent bacteria, but this was not common.



TEXT FIG. 2.—*Oxymonas di-undulata* n.sp.
From living material, showing three stages in the extension of the proboscis. In b the flagella were not visible.



TEXT FIG. 3.—Some late dividing stages of *Oxymonus diundulata* n.sp. (a) Two nuclei present but axostyle not completely divided, still single at posterior end. (b) Two distinct axostyles present and four undulating membranes. (c) Division to form four nuclei and four axostyles has taken place without the formation of separate individuals. In (a) and (c) the undulating membranes were not visible.

In fixed material the clear rod (axostyle of Kofoid and Swezy) stains readily, bright red with Mallory's Triple after Zenker or Schaudinn's fixative and grey or black with Heidenhain's iron-alum, but when this is counter-stained with acid Fuchsin, it is again bright red. The proboscis is a clear structure and can be seen to continue up to the base of the nucleus. The axostyle lies over one side of the nucleus and is closely applied to the nuclear end of the proboscis. Just beyond the termination of the axostyle there is a darkly staining body, the blepharoplast, from which the flagella arise (Pl. 43, Fig. 6 blp.). The nucleus is spherical, varying in diameter from 5·6μ to 6μ. There is an eccentric karyosome with a distinct halo. Deeply staining large granules (Fig. 6g), the siderophile granules of Kofoid and Swezy, can be seen in the cytoplasm.

Some late dividing stages were observed (Text Fig. 3). One live specimen was seen to have two nuclei, two axostyles and four undulating membranes.

Discussion.

This flagellate has characters agreeing with those of the genus *Oxymonas,* but there are striking differences between it and the species which have been described elsewhere. Kofoid and Swezy (1926) consider the genus to have diverged from the condition seen in *Monocercomonas* (which is the tri-flagellate type) in two directions. The first is the duplication and modification of the neuromotor system. This duplication has not occurred in *O. di-undulata* as there is only one blepharoplast present, also, in this species there are but two flagella, each with its undulating membrane. It could be hardly, therefore, termed a triflagellate unless perhaps it has been reduced.

The second direction is in the development of a protrusible anterior process. The possession of this striking process also by *O. di-undulata* justifies the inclusion of this flagellate in the genus *Oxymonas.* No proboscis sleeve was observed.

Trichomonas agilis n.sp.

Host: Calotermes brouni.

Diagnosis: Length, 10μ–13·6μ; width, 7μ–9μ; pyriform to ovoid; three anterior flagella; fourth trailing flagellum three times length of body, with undulating membrane which does not extend to the posterior end; well marked costa; nucleus pyriform situated anteriorly.

The shape of the body varies from pyriform to ovoid in the more slender forms, the size being from 10μ to 13·6μ long and 7μ to 9μ wide. It tapers to a point anteriorly where there is situated a single blepharoplast from which arise three long flagella projecting anteriorly. The undulating membrane does not extend right to the posterior end (Pl. 44, Fig. 7). At the base of the undulating membrane is a well marked costa which stains bright red with Mallory's Triple stain (Kirby, 1931). The flagellum attached to the undulating membrane arises from the blepharoplast and continues free beyond the body about twice its length.

The movement of the organism is rapid and jerking. The axostyle is seen projecting from the posterior end (Pl. 44, Fig. 7), but it is not visible further within the body. The nucleus is situated close to the anterior end. It is pyriform, tapering anteriorly, and

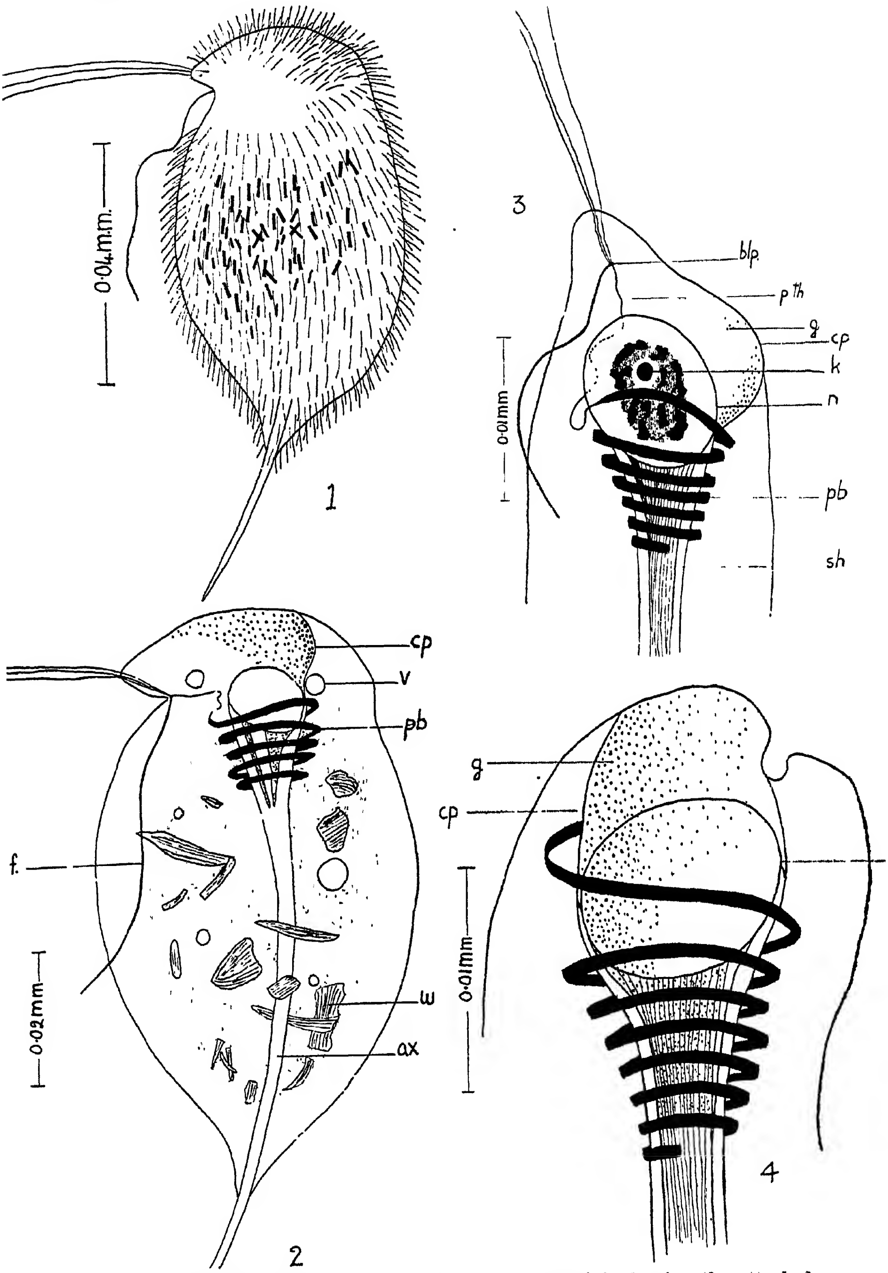


FIG. 1.—*Caduceia calotermidis*, n.sp., from living material, showing the attached spirochaetes and the rod-like micro-organisms.
FIG. 2.—*C. calotermidis*, n.sp., entire individual (spirochaetes omitted) from living specimen, stained with trace of alcoholic iodine.
FIG. 3.—Detail of neuromotor system. Mallory's Triple stain after Schaudinn. Granules, blepharoplast flagella and karyosome red. Parabasal body dark blue. Dotted line shows continuation of parabasal thread behind nucleus. Side view.
FIG. 4.—View from side opposite blepharoplast showing continuation of axostyle over one side of nucleus forming capitulum.

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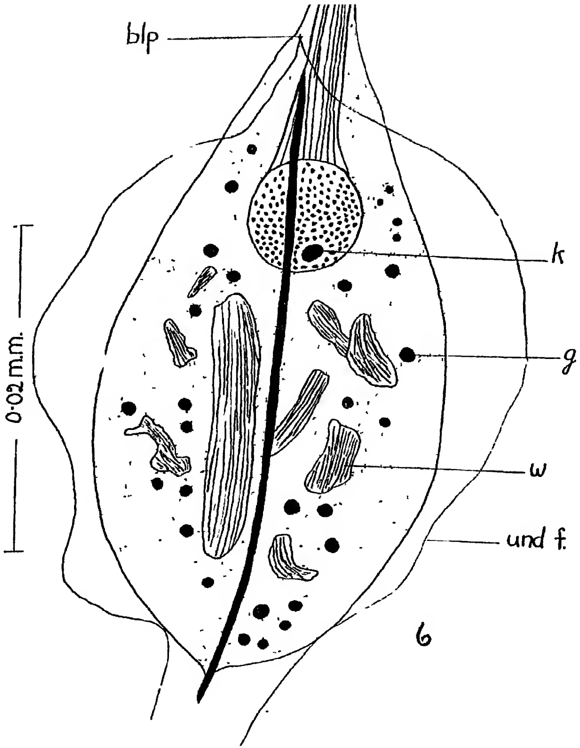

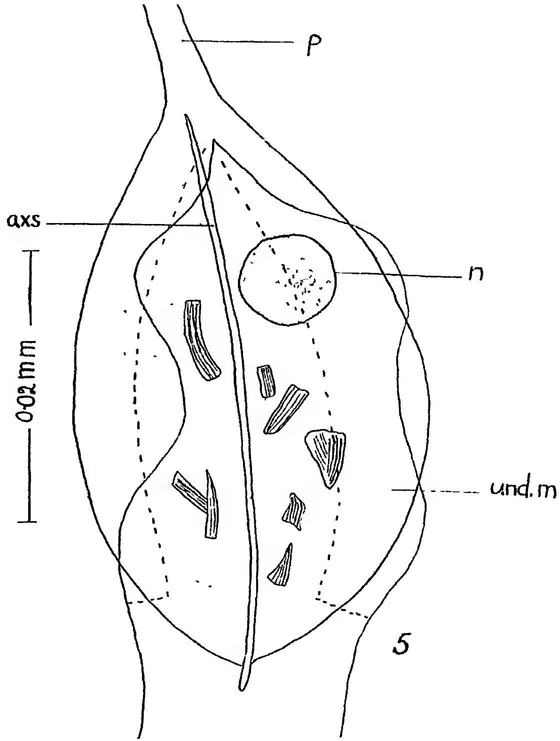

FIG. 5.—From living material. Length 30.6μ, width 22.9μ, nucleus 6μ in diameter, proboscis 53.5μ. Dotted lines indicate region of undulating membrane.

FIG. 6.—Entire individual, differently viewed from Fig. 5. (Proboscis not all included.) From specimen stained with Mallory's Triple after Zenker.

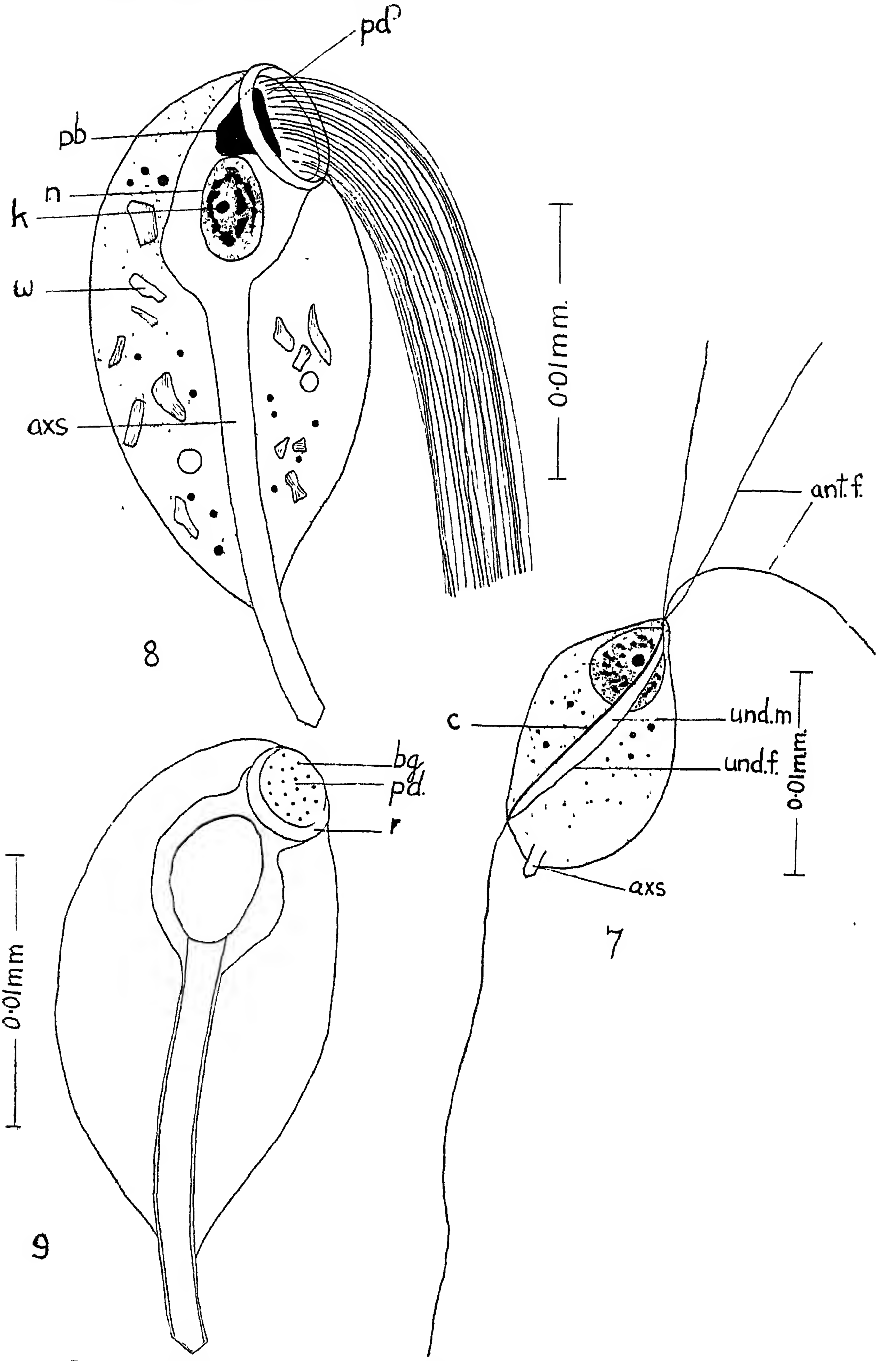

FIG. 7.—*Trichomonas agilis*, n.sp. (Mallory's Triple stain after Schaudinn.)

FIG. 8.—*Cyclojoenia australis*, n.gen., n.sp. (Mallory's Triple stain after Zenker's.)

FIG. 9.—*C. australis*. View looking into circular depression showing arrangement of basal granules. Flagella not shown.

measures one-third the length of the body. There is an eccentric karyosome with a halo. Numerous staining granules are present in the cytoplasm, but wood particles have not been identified.

Genus Cyclojoenia nov.

Joeniidae characterised by the possession of a circular plate-like depression bordered by a stout rim, from which arises the tuft of flagella. Flagella arise from basal granules evenly distributed over circular depression.

Genotype: *Cyclojoenia australis* n.sp.

Cyclojoenia australis n.sp.

Host: Stolotermes ruficeps.

Diagnosis: Length, 18·4μ–22·9μ; width, 10·7μ–15·3μ; pyriform, tapering posteriorly; about 20 flagella; stout axostyle which projects from posterior end; anteriorly it swells out and surrounds ovoid nucleus, it continues to rim surrounding circular depression; triangular parabasal body.

The flagellate is pyriform in shape, tapering posteriorly. The flagella project from a depression at the anterior end (Pl. 44, Figs. 8 and 9), which is bordered by a stout circular rim. There are at least 20 flagella, and these project backwards, lying alongside the body when the organism is at rest. They are slightly longer than the body. The organism moves rapidly in a jerking fashion by means of the flagella. They are raised towards the anterior end, the movement of each flagellum beginning proximally. They are then flicked rapidly to its side in metachronal succession.

The size ranges from 18·4μ to 22·9μ in length and from 10·7μ to 15·3μ in width. The axostyle (Pl. 44, Figs. 8 and 9), which is stout and sharply pointed, projects from the posterior end a distance of 6·1μ to 9μ in the large forms. The organism is xylophagous.

In the fixed and stained material the stout axostyle is almost colourless (pale mauve in Mallory's Triple stain). Anteriorly it swells out to surround the ovoid nucleus (Pl. 44, Figs. 8 and 9) and then appears to continue on to the circular rim surrounding the depression. The flagella appear to arise from the basal granules (Pl. 44, Fig. 9) evenly distributed over the circular plate-like depression. The karyosome present in the nucleus is eccentric and surrounded by a halo (Pl. 44, Fig. 8). There is a triangular parabasal body which lies above the nucleus (Pl. 44, Fig. 9 pb.) and the base of the triangle appears to be attached to the depressed area from which the flagella arise.

Discussion.

Cyclojoenia is very closely allied to the genus *Microjoenia* family Joeniidae, first described by Grassi on *M. hexamitoides*. He compares the anterior end to "an operculum of a lake containing fluid," from which the flagella arise in longitudinal rows. Cutler (1920) in his description of *M. axostylis* describes the flagella as arising from a series of granules arranged in two or three longitudinal rows. Both these species have a stout hyaline axostyle. *Cyclojoenia* resembles *Microjoenia* in size, in the possession of a stout hyaline axostyle which continues to the anterior end, and also in the possession of a tuft of flagella which arise from the anterior end. The basal granules

of the flagella, however, are arranged evenly on a depressed circular plate around which is a stout rim. This arrangement of the neuromotor system is considered sufficient to justify the establishment of a new genus, *Cyclojoenia.* Sutherland (1933) records two genera of the family *Joeniidae* from Australia; *Joenina pulchella* Grassi from *Porotermes grandis* Holmg. and *Staurojoenina assimilis* from *Calotermes oldfieldi* var. *chryseus.*

ACKNOWLEDGMENTS.

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ABBREVIATIONS.

(Figures based on free-hand sketches.)

ant.f.—anterior flagella.
ax.—axostyle.
bg.—basal granule.
blp.—blepharoplast.
c.—costa.
cp.—capitulum.
g.—granules.
k.—karyosome.
n.—nucleus.
p.—proboscis.
pb.—parabasal body.
pd.—plate-like depression.
pth.—parabasal thread.
r.—circular rim.
sh.—axostyle sheath.
trf.—trailing flagellum.
und.f.—undulating flagellum.
und.m.—undulating membrane.
v.—vacuole.
w.—wood.

Transactions of the Royal Society of New Zealand, Vol. 74, Part IV, pp. 315–319.

Note on the Movement of Waste on Screes in the Orongorongo District, near Wellington.

By Greta B. Stevenson, Messines Road, Karori, Wellington.

[*Read before Wellington Branch, September 27, 1944: received by the Editor, September 28, 1944; issued separately, March, 1945.*]

Summary.

Observations and measurements of banded screes in this district indicate that stone stripes are produced by the removal of fine waste by parallel, subsurface streams. A comparison is drawn between erosion on the screes and erosion in arid and semi-arid climates on the basis that in both cases there is a great excess of loose waste material, so that the flowing water acts as a transporting agent only, and does not directly shape the landscape. A further example of a land form shaped by weathering of the rock and the transportation of the resulting waste by water is pointed in the case of convex hills.

On the hills forming the eastern side of the Orongorongo River Valley numerous landslides have occurred. The scars of many are still visible from Wellington. Wherever the slump scarp has exposed the shattered greywacke of which a large part of the top of the hills is composed, long and wide screes have developed. Some are about 300 m. in vertical height and about 0·75 km. in width. In other places, landslides have exposed fault pug and brecciated rock in which extensive gullying has taken place, with the consequent development beneath the scarp of fans of rubble and clay.

The screes in the Wellington waterworks area have been studied by the writer during the years 1941–44. It has been found that the screes typically show marked, longitudinal striping. Bands of coarse boulders, averaging roughly 0·3 m. in diameter, alternate with bands of smaller stones, averaging roughly 0·1 m. in diameter. The bands on any one scree may be approximately the same width or the bands of larger stones may be narrower than the bands of smaller stones. The bands are from 1 to 3 m. wide. The smaller screes may present a flat surface from side to side but the larger screes tend to be domed slightly between a point on one side and a point of the same altitude on the opposite side. In places the bands of larger stones lie in perceptible dips, forming very shallow, parallel gullies.

Between the mouth of the Orongorongo River and the mouth of the Mukumuku there are a number of small shingle slips on the slopes rising from the coast. These slips probably owe their origin, in part, to the weakening or destruction of the vegetative cover by burning and overgrazing and the subsequent exposure of the shattered greywacke, which very readily forms screes. Here also is shown the same banding of large and small stones. One small, shallow scree which runs through a grove of isolated trees was seen in October, 1941, with driftwood scattered down the stripes of large stones.

In the same district are a number of boulder fans, some about 0·5 km. wide, formed on the narrow level strip of marine terrace between sea and hill, by small streams that flow in steep, narrow gullies down the hill. These fans show a network made of zones of large stones surrounding roughly polygonal centres of smaller stones. The fans are roughly half-cone shaped, but in most places the larger stones are slightly below the surrounding surface, when they appear similar to braided water channels. One fan is conspicuous in that it has become covered with sward except for the anastomosing lines of large stones.

It has been suggested that similar segregation of stones observed in other parts of the world (Sharpe, 1938) and in New Zealand (Zotov, 1940) is due to the action of frost. However, the following observations on the Orongorongo screes do not agree with this frost theory.

Very low temperatures such as would be necessary to freeze the ground to a depth have not been recorded in this area. Mr. Eric Riddiford, resident at the mouth of the Orongorongo River for the past 60 years, informs the writer that he has not seen the ground in his garden frozen, and that lemons and tender plants grow well there. Rainfall, however, is heavy. At the waterworks rainfall station the average annual precipitation for the last 15 years is 127·8 inches.

On the shingle slips examined, the stones were found to be moving rapidly down hill. Horizontal lines were marked on three slips by spilling roadmarking paint at intervals between two points of the same altitude on opposite sides of the scree. After three to four months most of the painted stones had rolled down the slope distances of from a few decimetres to 10 m. After nine to ten months the marks were lost. There was no indication that stones on any part of the scree moved faster than on any other part for the short period over which the marks remained visible.

On May 2, 1941, a line was marked across a scree in the waterfall branch of Ryan's Creek, a tributary of the Orongorongo River. When the site was revisited on June 8 of the same year a new landslide had occurred. The mountain above the original line presented an unstable face of shattered greywacke and argillite. From this face about 100 m. above the original line, a slump block roughly 20 m. across had fallen, leaving an arcuate scarp in the shattered rock. The block had largely crumbled to form fresh scree which had overwhelmed most of the painted line. Already there was incipient banding on this new scree. One month later there were well defined bands of larger and smaller stones. The stripes of larger stones widened and coalesced at the base where they joined together in a steep transverse gully full of large stones.

It is suggested by the writer that the bands of larger stones mark the position of subsurface watercourses. When rain falls, all the water that reaches the scree through its surface or by seepage or runoff from higher ground, is absorbed immediately into the porous shingle. It flows downhill through the interstices between the coarse waste which extends about 1 to 2 m. below the surface. It may be assumed that small fragments will be moved down hill

by the subsurface flow. In places at the edges of some screes there is much fine material of the size of peagravel and sand completely filling all the larger void spaces. This is taken to indicate that in the deepest parts of the screes there are no large void spaces, and ground water probably is present. It might be expected that the water which flows within the layer of loose waste material would move as a sheet, but in some manner it becomes concentrated in equal, parallel strips from which so much fine waste is removed that only coarse boulders are left on the surface. Similarly, on the more gently sloping boulder fans the water flowing within the loose waste collects in more or less equal anastomosing streams. The supply of fine waste on the scree is in excess of the carrying power of the water, so that usually enough of the smaller waste finds its way into the stripes of large stones to prevent these from developing into superficial gullies. The rock beneath the scree remains protected from the flowing water by a layer of closely packed fragments.

The parallel channels developed on limestone blocks and rarely on other rocks and described as lapiés (Cotton, 1941, p. 280) appear to result from a similar concentration of flowing water into more or less equal, parallel streams. The closely spaced, parallel gullies which are formed by the initial erosion of a soft, porous terrain on a steep slope—e.g., the drainage pattern on volcanic "shower" material described by Cotton (1941, p. 57) appear also to be analogous. In the loose waste of the scree slopes where gully forms do not result, the watercourses remain closely spaced and parallel, while, on the other hand, the pattern of the V-shaped gullies of bad-land erosion rapidly changes as some are enlarged by chance at the expense of others.

At the toe of the scree the bands of smaller stones disappear and a zone composed of only large boulders extends over a gradual and diminishing slope. On all the screes observed in the Orongorongo, a painted line across the middle of the slope showed that at this point the stones were moving rapidly downhill. The scarps at the head of the screes consisted of shattered greywacke cliffs up to 15 m. high, from which the supply of waste was continuous. At the foot of each scree was a tongue of large boulders up to 1 m. in diameter, many of which carried crustaceous lichen colonies several centimetres across. This indicated a more stable zone where the stones had not been disturbed for a period of perhaps ten years or more. The smaller sized waste material on the scree appears to be moved by the agency of running water through the interstices beneath the large boulders. If this is in fact the case, it may be anticipated that if a large scree were cut into by a river and a cliff formed across the toe of the slope, temporary streams would emerge during heavy rain from a layer below the surface boulders. Fans of fine waste would be expected to form at the outlet of these streams.

Certain points arising from this study of screes appear to be of interest in considering other forms of erosion. Conditions on the scree simulate conditions of aridity. There is no continuous plant cover or soil. There is a large amount of coarse, loose waste on the surface and, although the amount of water reaching the scree may

be considerable, it flows only beneath the surface. Also it is suggested that, because the supply of waste is in excess, the flowing water is always laden to capacity and acts solely as a transporting agent, moving waste material in more or less broad sheets down slope. The water can have no cutting action on the terrain.

In arid and semi-arid climates there are many wide plains with little or no soil and scanty vegetation. They are covered with loose waste material that is highly absorptive like the scree. On these porous plains there will be little or no runoff from such a surface and water, therefore, will not collect in streams or rivers to any extent. It is suggested that what water there is after rain will flow largely within the mantle of waste, as it does on the scree, spreading the stones in layers, and so tending to produce a flat surface.

On the bare residual mountains of the arid landscape, however, the runoff of all precipitation will be immediate and complete. Where the total precipitation though irregular is yet considerable—e.g., in the savanna type of climate, the runoff from the mountains will be very active. It will sweep all the waste from the continuing decay of the residuals away from their bases and may form watercourses or even rivers around the foot. If, where the more arid climate prevails, there is not sufficient rainfall to spread all the waste from the residuals, there will be some accumulation of scree around the base of the mountains. Thus the action of flowing water in these deserts will be to transport the waste resulting from the chemical and physical weathering of exposed rocks in such a way that nearly level plains are formed from which the steep sided residuals arise abruptly.

In the early development of an arid plain when a change from normal to arid climate occurs, great accumulations of waste may result from the accelerated erosion on steeper slopes following the loss of vegetative cover. In any case under arid conditions large amounts of waste are considered characteristic of the early stages of the cycle. The higher and steeper parts of the landscape which become bare are freely exposed to the atmosphere and continue to weather. Periodic sheet floods spread the waste material so that extensive plains of aggradation result (Cotton, 1942, p. 251). Parts of the terrain which are deeply buried will not weather so fast as parts freely exposed to the atmosphere. Weathering occurs down to the level of the ground water (Cotton, 1942, p. 21) apparently because the oxygen of the atmosphere circulates in the cavities not filled by water. This level may be at a considerable depth below the surface on an arid plain.

Following the period of aggradation, the action of the periodic floods of water is to spread the waste material out in sheets at lower and lower levels. The more elevated parts of the terrain beneath the plain of aggradation will become more exposed to the action of the atmosphere and also to the physical action of heat and cold and will decay faster than parts more deeply buried. As the level of the plain is gradually lowered the continued weathering of the buried rock nearest to the surface will tend to produce a plane rock surface beneath a veneer of waste material.

The statement that rock decay proceeds faster under a thin layer of waste than under a thick layer may be quoted also in an explanation of the development of convex land forms. The soil cover which constitutes the bulk of the mantle of waste under these conditions when it is saturated with water and flows in a mass (soil "creep") may be assumed to have considerable coherence and to flow as an extremely viscous liquid. On a convex surface the effect of such flow would be the thinning of the layer of waste on the flat top of the convex hill, in the same way that a layer of pitch laid over a dome will flow away first from the highest point. On a hill with a convex surface the top has the thinnest cover of soil, and is presumed to be the point where rock decay will be most rapid. In these terms an explanation may be made of the development of hills of continually gentler slope by the production and removal of rock waste more rapidly from the almost flat top of the convex surface than from its more steeply sloping sides.

The conclusion may be drawn that while valleys generally are the result of the work done by the rivers which have occupied them, the interfluves are mainly reduced by the processes of weathering. The removal of the products of weathering by flowing water in the form of sheet-floods and rill wash and by mass movements aided by water allow the processes of rock decay to continue. The material from the convex hills is delivered into the valleys where graded rivers which have finished their work as agents actively shaping the landscape, continue the work of transportation of the waste. While the hills are slowly reduced, the valley floor will be maintained at about the same level, so that river and valley bottom may show but little change in a period during which the hills on either hand are considerably lowered.

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Investigation of the Stomach Contents of New Zealand Fresh-water Shags.

By R. A. Falla and G. Stokell.

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Introduction.

The Cormorants of New Zealand, or Shags, as they are more commonly called, can be divided into three groups for which a convenient distinguishing key character is the colour of the feet.

1. The yellow-footed group, consisting of the closely related species *Phalacrocorax punctatus*, *P. steadi*, and *P. featherstoni*. For these the sub-generic *Stictocarbo* may be used. They have a restricted distribution on rocky coasts adjacent to deep water, and the last two have a narrow geographical range at Stewart Island and the Chatham Islands respectively.
2. The Flesh-footed or Pink-footed group. These are the sub-Antarctic shags, with a local race inhabiting each of several islands. They are exclusively marine and their affinities with several circum-polar species are fairly close. The New Zealand forms, however, are sufficiently distinct to be considered endemic. The species at present recognised are:—
   P. carunculatus—Western Cook Strait.
   P. chalconotus (including *P. huttoni*)—Otago and Stewart Island.
   P. ranfurlyi—Bounty Islands.
   P. onslowi—Chatham Islands.
   P. colensoi—Auckland Islands.
   P. campbelli—Campbell Islands.
3. Black-footed Shags. This group consists of the cosmopolitan species *P. carbo* (the Black Shag), *P. varius* (the Pied Shag), *P. brevirostris* (the White-throated or Little Pied Shag) and *P. sulcirostris* (the Little Black Shag). These species all occur in Australia, and the New Zealand races are hardly distinguishable. None of them has an exclusively fresh-water range but all inhabit the lake and river systems in varying degrees. The Pied Shag does not as a rule range beyond estuaries. The Little Black Shag has a restricted fresh-water range in the North Island only, while the other two range inland throughout New Zealand, and the Black Shag in particular may be found on any stream or lake. Although thus widely distributed, however, it cannot at the present time be considered abundant.

Distribution of Black Shags.

It is evident from general summaries, such as that of Stead (1932), that the Black Shag is much less abundant in New Zealand than formerly. It is difficult to get comprehensive information on the number of breeding colonies but this could probably be done in the near future owing to the Dominion wide coverage of the recently

formed Ornithological Society of New Zealand. From the publications of the first three years of activity of this Society, 1941-44, the following information has been derived.

From North Auckland there are no records of large numbers, and only some colonies of less than a dozen nests are recorded by observers in this area. In the Lower Waikato the nesting headquarters appear to be Lake Waikare, where the number of nests, perhaps 200 in 1934, appears not to have increased in the last 10 years. From Taranaki and Northern Hawke's Bay no recent records are available, but for Southern Hawke's Bay Mr C. A. Fleming has contributed the following (*Ann. Rept. O.S.N.Z.*, 1941):

> "In six months in S. Hawke's Bay every Black Shag seen was noted. Though anglers report this species as abundant in the Manawatu and other trout streams, there were only 42 birds recorded in this area, and less than 100 in the whole district. Odd birds were seen at Kumeroa, Mangatiwainui, Mangatainoka, Dannevirke, Mangapuaka, Wanstead, Purimu Lake, Blackhead (coast) and lakes behind Blackhead. Flocks (over 12) at Manawatu near Tamaki Junction and north of Kumeroa, where there are regular roosting-places, and at Poanui, N. of Pourerere, where, on 23/5/41, numbers of birds had fine white flank patches and were making regular trips with nesting-material from Poanui to a point at least two miles north, where undoubtedly there is a nesting-colony. A further colony is reported at Hatuma Lake, south of Waipukurau."

From Wairarapa and Palliser districts small colonies of up to 30 nests that have not increased over a number of years are reported, but at Gollans Valley, near Wellington, a colony observed at intervals by one of us (R. A. F.) since 1930, when there were 40 occupied nests, had dwindled to 20 nests in 1932, 12 in 1934, and finally had been found abandoned in 1942. It is not known if any survivors moved elsewhere, but the indications are that this colony has been exterminated.

The numbers recorded in Nelson and Marlborough are somewhat larger than from other districts, and flights of up to 300 birds have been recorded moving from the Waimea Plains towards the coastal region of the Sounds. The resident population of Marlborough would also number several hundreds. In Canterbury the coastal cliffs east of Lake Ellesmere and Forsyth still afford a nesting sanctuary for a scattered colony of several hundred birds. In the back country, nesting colonies are widely separated and of comparatively small size, such as those of the Wilberforce River and at Waimate, from which samples have been examined in the preparation of this paper. No full records are available from Westland, Otago, and Southland, but the species is fairly common in all three districts.

Method of Presenting Results.

Adequate investigation of the feeding habits of cormorants in the lake and river systems of New Zealand is long overdue. In comparison with the vigorous expression in the popular press of a prejudice against shags that has now become traditional, there is to be found as yet no publication of a detailed analysis of shag food

in New Zealand that could be used with confidence by a student of ornithology or of the conservation of a balanced fresh water fauna.

The present contribution does not claim to make good the deficiency: the data offered, although significant, are both meagre and incomplete. In a paper read in 1937, but published only in abstract, one of us (Falla, 1937) has outlined the requirements of such an investigation as

(a) A census of the nesting colonies of each species.

(b) Determination of the complete annual food cycle of each species.

(c) Analysis of results to determine whether in the ecology of streams and lakes any cormorant food is taken to such excess as to cause depletion.

At the time of writing, none of these conditions has been fulfilled, but some significant samples have been analysed from four separate districts, and it is considered that a listing of these results gives enough information about the feeding habits of shags on inland waterways to warrant publication.

The available records are here presented separately for each locality investigated. It seems that they would in this way have some comparative value, as the conditions of food supply in various areas are quite dissimilar. The numerical method of recording stomach contents has been followed as it seems on the whole better than any attempt to make volumetric analysis or to indicate the relative bulk of the various foods. The individual food organism is therefore regarded as the unit. Where available, some details of the exact locality and time of day at which the birds were collected are given. On this point, Dr. Scaife Armstrong has remarked in a letter covering the forwarding of his results:

> "I have put in the locality where the birds were shot as it seems to me that this is of first importance in the type of food taken, for the birds go to definite fishing grounds for certain kinds of food and then when fully fed go to a resting place where they are shot. If the birds are shot on the old jetty at Tokaanu or the dead tree by the Waihi marshes they will usually be found to have fed on carp, if shot at the Old Orchard at the mouth of the Waikato River, Taupo, *Galaxias*, Mototere Point, *Gobiomorphus*, and so on, so that the percentage of the birds that live on any definite food could be varied to a large extent by the site where the shooting takes place."

Acknowledgments.

Thanks are due to Dr. J. Scaife Armstrong for his permission to publish his Taupo results, and to the Waimate Acclimatisation Society for responding to a request for shags for examination.

First Locality Group.

Locality: Lake Taupo, near Waikato River outlet.

Dates: Various between May, 1929 and November, 1936.

Collector: J. Scaife Armstrong.

Recorder: J. Scaife Armstrong.

(a) Black Shags (*P. carbo*). All adult.
Number of birds examined, 15, of which only 7 contained food.

Food organisms.	No. of birds in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Salmo sp.	3	3	5
Galaxias sp.	1	1	1
Carassius sp.	1	1	1
Unidentified	2	—	—
Plants—			
Green Weed	1	—	1

(b) White-throated and Little Pied Shags (*P. brevirostris*).
Number of birds examined, 40, of which 35 contained food.

Food organisms.	No. of birds in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Galaxias sp.	6	6	12
Gobiomorphus sp.	14	8	63
Carassius sp.	2	2	3
Unidentified	9	—	—
Crustacea—			
Paranephrops	6	4	12
Insects—			
Trichoptera, larvae	1	—	—

The series of *P. carbo* is not large enough to give a reliable indication either of diet range or food preference. It may be remarked that a high proportion (8 out of 15) had no food in the alimentary tract when shot, indicating that feeding is not a continuous process, although of course there is the possibility that such birds may have been taken early in the day before feeding had commenced.

The record for *P. brevirostris* is based on a better series and it indicates a strong preference for *Gobiomorphus* followed by *Galaxias* and Koura (*Paranephrops*). There are no trout over the whole period of seven years in an area where they are abundant. The record also includes the first reference known to us of the finding of the larvae cases of Caddis Fly in the stomach contents.

Second Locality Group.

(Black Shag.)

Locality: Lake Waikare, Waikato.
Date: September, 1931. (Time, between noon and 3 p.m.)
Collector: A. T. Pycroft.
Recorder: R. A. Falla.

Number of birds examined, 11 adults, all of which contained food.

Food organisms.	No. of birds in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Anguilla sp.	11	3	20

The birds were feeding young in a nesting colony, and the figures are of interest only as indicating a local preference where eels are available, and other food probably not so easily accessible.

Method in Later Samples.

The method of examination employed in the preparation of the following tables differs from that of Serventy (1938, p. 298) in so far that the whole of the fragmentary material representing the remains of past meals has been subjected to analysis. When fishes occur in the stomachs it is seldom that a complete specimen or even a considerable portion thereof is present, and the following deter-

minations are carried only so far as the actual material permits. A single bone or scale may be specifically identifiable, and where this is so the species is recorded, but on the other hand a much greater quantity of material may not justify more than a family determination. In some cases only the order to which a fish belongs may be determined, and when not even this is possible specimens are recorded merely as fishes. In essaying any interpretation of these restricted determinations it is necessary to give consideration to the locality from which the material was obtained. A fish of the order Isospondyli taken at Lake Ellesmere might be a Galaxiid, a Salmonoid, a Clupeoid, or a smelt, but if taken at the Wilberforce River would necessarily belong to one of the two former groups. An Eleotrid from Lake Ellesmere would almost certainly belong to the genus *Gobiomorphus* and in all probability would be *G. basalis,* but one from upland waters would most likely be *Philypnodon breviceps.*

It is also to be noted, when dealing with nestling birds, that parts of a single fish may have been fed by the parent to each of several nestlings, and the species thus given a false value in the tables.

In determining insects and other animals everything identifiable has been counted. The figures, particularly of caddis larvae cases, must be regarded as approximate, as many fragments are not readily distinguishable as the partly digested remains of a complete case or as separated portions.

Third Locality Group.

(Black Shag.)

Locality: Lake Ellesmere. (The first 6 birds taken at Birdlings Flat flying to cliff nests from Lakes Ellesmere and Forsyth; time, between 3 p.m. and 5 p.m.; remainder taken at mouth of Selwyn.)

Collectors: E. F. Stead and D. Hope.

Recorder: G. Stokell.

Adults.

Serial Number.	Food organisms and other material.	
1	*Anguilla* sp.	1
2	*Rhombosolea* sp.	1
	Eleotrid fish	1
	Isospondyli fish	1
	Mollusca (*Corneocyclas*)	5
3	Piece of felt. Apparently remains of a gun wad	
4	*Anguilla* sp.	1
	Traces vegetable matter	
5	*Anguilla australis*	1
6	*Anguilla australis*	3
	Anguilla sp.	3
7	*Gobiomorphus basalis*	1
	Eleotrid fishes	8
	Pairs of otoliths similar to those of Eleotrids	39
	Waterweed (*Elodea canadensis*)	
8	*Gobiomorphus basalis*	6
	Eleotrid fishes	4
9	Eleotrid fishes	4
	Pairs of otoliths similar to those of Eleotrids	23
10	Pairs of otoliths similar to those of Eleotrids	½
	Mollusca (*Potamopyrgus*)	4
	Trichoptera, larvae	5
	Seeds of (?)	7

11	Pairs of otoliths similar to those of Eleotrids	2
	Hemiptera, adult	1

A Summary of these data is given below.

Number of birds examined, 11 adults, 10 of which contained food.

Food organisms.	No. of birds. in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Anguilla	4	6	9
Rombosolea sp.	1	1	1
Eleotrids *	4	10	24
Isospondylid Fish	1	1	1
Molluscs—			
Potamopyrgus sp.	1	4	4
Corneocyclas sp.	1	5	5
Insects—			
Trichoptera, larvae	1	5	5
Plants—			
Elodea canadensis	1	—	—
Seeds of (?)	1	7	7

* Figures given in Summary take no account of large accumulation of otoliths.

Fourth Locality Group.

(Black Shag.)

Locality: Waitaki River.
Date: November 25, 1938.
Collector: Waimate Acclimatisation Society.
Recorder: G. Stokell.

Adults.

Serial Number.	Food organisms and other material.	
1	*Philypnodon breviceps*	1
	Salmo trutta	1
	Archichauliodes dubitatus larvae	21
	Nestlings.	
2	*Archichauliodes dubitatus* larvae	1
	Trichoptera, larvae	6
	Plectoptera, larva	1
	Pieces of Rock	4
3	*Salmo trutta*	1
	Salmonoid fish	1
	Trichoptera, larvae	824
	Coleoptera, adult	1
	Unidentified arthropod (fragments)	
	Traces vegetable matter	
	Piece of bark	1
	Pieces of coal	3
	Pebble	1
4	*Salmo* sp.	1
	Trichoptera, larvae	263
	Unidentified arthropod (fragments)	
	Piece of wood	1
5	Isospondylid fish	1
	Trichoptera, larvae	438
	Unidentified arthropod (fragments)	
	Piece of rock	1
6	Trichoptera, larvae	602
	Coleoptera, adults	6
	Hemiptera, adults	3
	Unidentified arthropod (fragments)	
	Pebbles	7
	Sand and grit	

7	*Salmo trutta*	1
	Salmonoid fishes	2
	Trichoptera, larvae	31
	Diptera, larvae	1
	Coleoptera, adults	2
	Archichauliodes dubitatus, larvae	3
	Willow leaf	1
	Gorse bloom	1
	Seed heads of thistle	2
	Other vegetable matter	
	Sheep dropping	1
	Piece of coal	1
	Grit	

SUMMARY.

Food organism.	No. of birds in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Salmo trutta or Salmonoid fishes	4	3	7
Philypnodon breviceps	1	1	1
Isospondylid fish	1	1	1
Insects—			
Archichauliodes dubitatus larvae	3	21	25
Trichoptera, larvae	6	824	1900
Plectoptera, larvae	1	1	1
Diptera, larvae	1	1	1
Coleoptera, adult	3	6	9
Hemiptera, adult	1	3	3
Miscellaneous material already listed above	6	—	—

This sample, although small, is of interest as representing the food of nesting birds. The quantity of insect larvae is striking, and the question arises as to its origin, whether gathered directly or as stomach contents already in fish captured.

The latter suggestion, while tenable in respect of some birds, is strongly discredited by several circumstances noted in others. Caddis larvae are usually associated in the stomachs with the remains of fishes, and when the number of the former is consistent with the size of the latter secondary derivation must be considered possible, but the tables provide instances of stomachs containing a quantity of caddis cases that could not have been derived from the fishes present. Disregarding the data from nestlings, which may not give a true indication of the feeding habits of the parent birds, it may be noted that the single fish of about five inches in total length which occurred in No. 5, Group 5, could not have contained the 500 caddis with which its remains were associated.

In some specimens the caddis cases were in the lower part of the stomach and in an advanced stage of digestion, but in others they were in the gullet and in so fresh a state that the animal could be removed from the case in perfect condition. It is scarcely conceivable that such larvae could have been in the shag's stomach long enough to have been digested out of a fish.

In waters such as the Upper Selwyn and the Wilberforce, Black Shags may be noted wading in shallow ripples, and frequently submerging their heads as if grubbing under stones. These shallow rapids are the habitat of numerous caddis larvae and of varying

numbers of all other types of aquatic larvae enumerated in the tables. They also harbour fishes, principally Eleotrids and Galaxiids of small size. At the time Group 5 was being collected shags were observed working the shallow ripples of the Wilberforce as described above. Whatever the nature of the food that was being taken it does not appear to have been fishes as the birds collected that day contained no Eleotrids and only a single determinable Galaxiid, the latter being larger than usually occurs in the open river. In Group 4, which contained numerous caddis larvae, no Galaxiids and only a single Eleotrid were present. The circumstances, therefore, strongly suggest that where shags are working shallow, rapid water they are gathering caddis and other larvae directly from the stream bed.

The size of the pebbles and pieces of rock taken from some shag stomachs further discredits the suggestion of secondary derivation. Stones are found occasionally in trout that have been feeding largely on caddis, the indication being that where several cases are attached to a small stone the whole mass is swallowed, but these stones are smaller than those contained by shags. Twenty-five per cent. of the latter are about ¾ inch in diameter, but it is very seldom that a stone of this size is found in trout, and it is to be noted that this applies to trout ranging from 9 inches to 16 inches in total length, whereas the fishes found in Groups 4 and 5 had a maximum of 6 inches. The ingestion of a ¾ inch stone by a 6 inch trout would appear to be a physical impossibility.

FIFTH LOCALITY GROUP.

(Black Shag.)

Locality: Wilberforce River, Canterbury.
Date: October 29, 1939. (Time, between noon and 3 p.m.)
Collectors: G. Stokell and members of the Methven Gun Club.
Recorder: G. Stokell.

Serial Number.	Food organisms and other material.	
	Adults.	
1	Salmonoid fishes	2
	Trichoptera, larvae	38
2	Salmonoid fish	1
	Trichoptera, larvae	137
3	Salmonoid fishes	3
	Trichoptera, larvae	38
4	Salmonoid fishes	3
	Flying Young.	
5	Isospondylid fish	1
	Trichoptera, larvae	500
	Coleoptera, adult	1
	Fragments of wood and roots	
	Piece of clay	1
	Piece of peat	1
	Much sand and grit up to pieces ¼in in length	
6	Fish	1
	Trichoptera, larvae	42
	Hemiptera, adult	1
	Mollusca (*Potamopyrgus*)	1
	Traces vegetable matter	
	Pieces of rock up to ¾in in length	16
	A little sand and grit	

7	Fish	1
	Trichoptera, larvae	37
	Mollusca (*Potamopyrgus*)	8
	Mollusca (*Isidora*)	2
	Waterweed (small quantity)	
	Pieces of rock from 3-16in to ¾in in diameter	25
	Nestlings.	
8	*Salmo trutta*	1
	Salmonoid fishes	2
	Trichoptera, larvae	148
	Archichauliodes dubitatus, larvae	2
	Gordius worms, larvae	3
	Fragments vegetable matter	
9	*Salmo gairdnerii*	1
	Trichoptera, larvae	157
	Archichauliodes dubitatus, larvae	2
	Pebble	1
10	Trichoptera, larvae	127
	Archichauliodes dubitatus, larvae	2
	Piece of wood	1
	Piece of bark	1
	Twigs, grass and other vegetable matter	
	Pebble	1
	Sheep droppings (globular)	6
11	Salmonoid fish	1
	Trichoptera, larvae	349
	Archichauliodes dubitatus, larvae	3
	Coleoptera, adult	1
	Diptera, larvae	1
	Sheep dropping	1
	Pebbles	8
	Piece of wood	1
	Piece of peat	1
	Traces vegetable matter	
12	Salmonoid fishes	3
	Isospondylid fish	1
	Trichoptera, larvae	169
	Archichauliodes dubitatus, larvae	2
	Coleoptera, adult	1
	Plectoptera, larvae	1
	Sheep dropping	1
	Traces vegetable matter	
13	*Galaxias* sp.	1
	Salmonoid fish	1
	Trichoptera, larvae	50
	Stenoperla prasina, larva	1
	Shot	1
14	Salmonoid fishes	2
	Trichoptera, larvae	89
	Archichauliodes dubitatus, larvae	2
	Procordulia smithii, adult	1
	Roots	
15	Salmonoid fish	1
	Fish	1
	Trichoptera, larvae	276
	Archichauliodes dubitatus, larvae	4
	Coleoptera (*Odontria*), adult	2
	Diptera, larvae	2
	Unidentified arthropod (fragments)	
	Fragments of roots	
	Pebbles	9
	Sheep dropping	1

16	Isospondylid fish	1
	Trichoptera, larvae	75
	Diptera, larvae	1
	Insect larva	1
	Pebbles	2
	Sheep dropping	1
	Fragments of roots and moss	
17	Salmonoid fishes	2
	Trichoptera, larvae	276
	Diptera, larvae	2
	Plectoptera, larva	1
	Coleoptera, adult	3
	Archichauliodes dubitatus, larvae	3
	Unidentified arthropod (fragments)	
	Sheep droppings	3
	Pebbles and splinters of stone	11
	Pieces of wood	2
	Piece of bark	1
	Leaves of rata	2
	Leaf of (?)	1
	Moss and roots	
18	*Salmo trutta*	1
	Isospondylid fishes	2
	Trichoptera, larvae	83
	Diptera, larva	1
	Coleoptera, adult	1
	Sheep droppings	3
	Pieces of wood	2
	Pieces of bark	3
	Pieces of rock. Largest $\frac{5}{8}$in in length	2
	Fragments of moss	

SUMMARY.

Number of birds examined: 4 adults, 3 fully fledged flying young, 11 downy nestlings (total, 18 birds, all containing food).

Food organism.	No. of birds. in which found.	Highest number in any one bird.	Total from all birds.
Fishes—			
Salmonoid fishes	13	3	24
Galaxias sp.	1	1	1
Isospondylid fishes	4	2	5
Undetermined fishes	2	1	2
Insects—			
Trichoptera, larvae	17	500	2594
Archichauliodes dubitatus, larvae	8	4	20
Procordulia smithii, ad.	1	1	1
Stenoperla prasina, larva	1	1	1
Plectoptera, larvae	2	1	2
Diptera, larvae	4	2	4
Coleoptera (including Odontria)	6	3	9
Molluscs—			
Potamopyrgus sp.	2	8	9
Isidora sp.	1	2	2
Miscellaneous matter listed above	14	—	—

These data agree so closely with those of the previous group, and the circumstances of locality and class of bird are so similar that the combined results may be regarded as giving a safe indication of the food of nestling birds on upland waters.

Conclusions.

The results listed above may be regarded as giving an estimation of the proportional composition of shag food (on a numerical basis) over a wide area and at various seasons. It yet remains to record the annual cycle from any one area.

The numerical basis of presenting results, although necessary as a first step and valuable in itself, is not finally sufficient for applying the results to an evaluation of the Black Shag in the ecology of lakes and streams. Either the volume or the weight of the various food organisms must eventually be considered. In practice, owing to varying degrees of digestion, direct measurement of stomach contents is unsatisfactory, and the indirect method recommended by Serventy (1938, p. 297) is to be preferred. He writes:

> "I have attempted to avoid the difficulty by recording, during the course of my investigations, the lengths (or probable lengths in the case of partially-digested organisms) of the various food species as they were counted, and it had been my intention to calculate their original weights from data obtained from lengthweight ratios of fresh material."

This has not been done in the present paper, but could be applied to the data as set out once the necessary length weight ratios had been worked out.

In view of the great mass of published material that has appeared in the daily press, in monthly journals and in annual reports purporting to be investigation, it seems desirable to point out some ways in which results of a carefully detailed analysis of stomach contents may modify conclusions more hastily reached. As an example of a moderate and well-intentioned report we may cite the following extract from the New Zealand Herald, 3/12/38, which records a local examination of a sample from Locality 4, taken at the same time and from the same colony as the seven birds examined by us:

> "In every case the birds were fully gorged with fish, evidently trout. In some cases the fish, which were swallowed whole, were seen to be of takeable size.
>
> "Mr. Cox, in commenting on the results of the drive, said that it was a telling refutation of the charge made by a northern society that the Waimate Society was convicting the shag of feeding on trout on slender evidence. 'When it is realised that the daily diet of a mature shag is about 2½lb of fish,' he said, 'and that at a low estimate there are about 800 shags between the dam and the river mouth, it is a wonder there are any fish in the river at all.'"

The first discrepancy is in the finding "fully gorged with fish, evidently trout," as compared with the more mixed diet indicated in the analysed sample. On the subject of the weight of food taken per day it may be remarked that although 2½lb is the lowest of such popular estimates that have come to our notice, its accuracy is open to question. It is difficult to estimate under open field conditions, but it is legitimate to point out that controlled experiment indicates that the average amount of food taken daily is the amount actually required, and that this average does not vary with conditions of

available food. Wetmore (1927), using caged cormorants in an enclosure, found that they were maintained in healthy breeding condition on an amount of fish varying from ¾lb to 1lb per day for six days a week. Although unable to experiment thus with shags we have been able to do so with penguins, and find ½lb to be the optimum daily requirement of a bird weighing 2¾lb. On the same rates a black shag's daily requirement would be about 1lb. Except in the case of some birds containing eels, the actual or estimated amounts of food found in any one stomach did not exceed this in any of the samples examined in the present investigation. Varying degrees of digestion down to practically empty stomachs are found, indicating that feeding is restricted to a portion only of the daylight hours, as field observers have already recorded (Stead, 1932, p. 9).

From the lists and analysis presented in this paper it should be possible to proceed to the third requirement—viz., an assessment of the place of shags in the whole ecology of lakes and streams. It may be pointed out that the motive of the present work is not vindication of the shag so much as a vindication of scientific method in approaching the question.

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The Genus *Pterocladia* in New Zealand.

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The genus *Pterocladia* has been widely collected over a long period by New Zealand algologists. Thanks to the generous co-operation of those responsible for the various herbaria, it had been possible to examine specimens from the following sources:—Herb. R. M. Laing (bequeathed to Canterbury College); Herb. W. A. Scarfe (presented to the Botany Division); Herb. V. W. Lindauer; Herb. Auckland Museum; Herb. Dominion Museum. The Auckland Museum collection, built up by Miss L. M. Cranwell, and the Laing Herbarium provide together a very useful set of examples from outside New Zealand. From this material, considered along with the fairly extensive series collected during a survey of seaweeds suitable for manufacture of agar in New Zealand (Moore, 1944), it appears that the characters of the genus have been rather narrowly limited, and that some points have been ignored altogether. The present paper offers supplementary data bearing on the broad question of generic diagnosis, and also attempts to state the conclusions reached about the relationships of the various New Zealand forms known to belong here. It is possible that, among our smaller plants at present attributed to the genus *Gelidium*, but not yet studied in detail, some may be found to be in fact *Pterocladia*.

The genus *Pterocladia* was set up by J. G. Agardh (1851, p. 482), based on the single species *Fucus lucidus R.Br.* (in Turner, 1819, p. 98, t. 238). The generic description, which is full and detailed, appears to have been drawn up, not from the original Australian specimens in the Brown Herbarium, but from later collected plants, which Agardh states did not agree in habit with the one Turnerian specimen he had seen. Agardh had descriptions subsequent to Turner's to draw upon, and probably had, among others, Hooker's New Zealand specimens under review when he set out his generic and specific characters. Thus, though the type specimen of *F. lucidus* must be one of Brown's Australian plants, the genus *Pterocladia* was based on other material.

The main diagnostic character of *Pterocladia* is the unilocular cystocarp with parietal placenta, and this was recognised by Bornet and Thuret (1876) in Gmelin's *Fucus capillaceus*, which had been merged in, or kept as a variety of, *Gelidium corneum*. Many features of *P. capillacea* do not fit into Agardh's detailed generic description of *Pterocladia*, based on *P. lucida* alone. More recently described species of *Pterocladia* include *P. pectinata* Lucas (1931), *P. nana* Okamura (1931), *P. tenuis* Okamura (1934), *P. densa* Okamura (1934), *Gelidium* (*Pterocladia*) *okamurai* Setchell and Gardner

(1937), *P. americana* Taylor (1943), and *P. bartlettii* Taylor (1943). In countries where only *P. capillacea* or near relatives grow, there has been a tendency to regard characters of the smaller *Pterocladia* as common to the genus, but this assumption is not always justified.

REPRODUCTIVE ORGANS.

In clearly defined margins of male sori, and in irregular disposition of tetrasporangia in their sori, New Zealand specimens agree with Feldmann and Hamel's account of the genus (1936, pp. 94–96). In some of the New Zealand material examined there was an indication of V-shaped series of tetrasporangia, but none were so obvious as those figured by Feldmann and Hamel in *Gelidium melanoideum* (*loc. cit.* Fig. 16) and the genus *Gelidiella*. Taylor (1943) records clear or obvious V-shaped rows in both *P. americana* and *P. bartletti*. The cystocarps examined showed some features of which no mention has been seen in the literature.

The Cystocarp.

Agardh pointed out in 1851 that while the cystocarp in *Gelidium* is double, projecting from both sides of the frond and with the placenta forming a wall between the two loculi, that in *Pterocladia* is single, projecting on one side only. He describes the liberation of the carpospores in *Gelidium*: "gemmidiis . . . demum de laceratione pericarpii a fronde liberatis"; in *Pterocladia*: "gemmidiis . . . per carpostomium demum emissis."

Harvey (1863, Pl. 248) says of *P. lucida* "conceptacles resemble semi-conceptacles of a *Gelidium*, as if one side only of the conceptacle were developed," but the carpostome of *Gelidium* is not described. Otherwise the dehiscence of *P. lucida* does not seem to be mentioned in the literature, and figures of sections of the cystocarp do not show any ostiole.

In *P. capillacea* the cystocarp is better known. Bornet's figure (1876) of a longitudinal section showing a single opening on a raised mound pointing towards the tip of the pinnule has been repeatedly reproduced. (Bornet's Pl. 20 shows also a T.S. of *Gelidium latifolium* with two opposite ostioles, not raised on special projections.) Feldmann and Hamel's Fig. 30B shows a twig of *P. capillacea* with numerous cystocarps in many of which the single ostiole can be seen at the top of a small projection. Of dehiscence in the family generally, these authors say only "Les carpostomes se percent." Okamura (1934) studying cystocarps of native Japanese species, describes the *Pterocladia* carpostome as "elevated more or less like a beak with a large and round opening, situated either vertically or a little obliquely towards the apex a little ahead of the middle of the median line." His Pl. 33 figures the cystocarps of his three Japanese species of *Pterocladia*, each with a single ostiole raised on a conical mound.

New Zealand specimens resembling *P. capillacea* in other respects have the characteristic conspicuous carpostome raised on a mound, often pointed and quite frequently directed rather towards the pinnule tip. Two, three, or occasionally as many as five carpostomes, all in the median line, may open from a single loculus (Pl. 45, Figs. 1–3), but usually there is only one.

In *P. lucida*, both New Zealand and Australian specimens, the surface of the cystocarp is smoothly rounded or vaguely cratered, without any conspicuous projection and no very obvious carpostome. (Pl. 45, Fig. 6). Slicing off the pericarp, of which Agardh (1851, p. 482) says "demum delabentia, excavationem in alterutera pagina reliquentia," and mounting it separately, shows clearly that each cystocarp has as a rule several carpostomes opening from one loculus. Each carpostome is slightly sunk below the general surface and is rimmed, though not so strongly as those of *P. capillacea*, with a clear structureless border. They are irregular in shape, from circular to slit-like, and disposed on the surface of the cystocarp without any uniform arrangement. On one frond different cystocarps may have one to six openings (Pl. 45, Fig. 7).

The appropriate part of the generic diagnosis should therefore read "cystocarp with one loculus opening to one or other surface of the frond by one or more ostioles."

Axis Structure as a Generic Character.

A characteristic feature of the family Gelidiaceae is the development, between the axis cells, of fine, non-septate, unbranched, thick-walled filaments, that are variously called rhizines, rhizoids, rhizoidal filaments, hyphae, or intercellular fibres.

Okamura (1934, p. 47) considers that "in the sterile state *Gelidium* is distinguished from *Pterocladia* by the difference of the arrangement of rhizoidal filaments. In the former they are, as a rule, thickly congested on the external side of the central tissue, and in that tissue few are scattered in younger parts of frond, becoming gradually denser as the part grows in age. On the contrary, in *Pterocladia* rhizoidal filaments are seen in the central tissue only, either densely or scatteringly. In both genera it is common to find a dense mass of rhizoids on both sides of branches, so that the cross section of branches shows densely congested rhizoids at both corners." He mentions as exceptions *G. vagum* and *G. pusillum*, which in some sections show a dense mass of rhizoids in the central tissue.

Feldmann and Hamel (*loc. cit.* p. 92) find that in *P. capillacea* "les rhizines sont localisées dans le tissu médullaire et font défaut dans l'écorce interne (Fig. 3, échantillon de Banyuls)". They use the rhizine grouping as a generic key character on page 97.

Setchell and Gardner (1937, p. 76) say "The presence of rhizoidal filaments in the centre of the medulla, as proposed by Okamura as a method of distinguishing the two genera, does not seem to hold in all cases."

Taylor (1943, p. 158), considering *P. capillacea* and *G. corneum*, remarks "The distribution of the rhizines in the stem is by no means clear-cut in many cases, and as a character must be used with caution."

In studying the structure of the frond Okamura took "for the sake of comparison, the sterile fronds of *Pterocladia lucida* and *P. capillaris*" (the latter presumably a misprint for *capillacea*) but he does not mention the source of this material.

Agardh's generic description, followed by Hooker, Harvey and later authors states: "Frons . . . stratis tribus contexta; fibris

interioribus longitudinalibus densissime intertextis, oblique in cellulas majores rotundatas excurrentibus, exterioribus cellulis minoribus, in fila moniliformia verticalia conjunctis.'' Thus one would expect *P. lucida* to conform to Okamura's scheme. Sections of Berggren's specimens from North Auckland, identified by J. Agardh as *P. lucida*, show, however, that this description applies only to older parts of the axes, and then only as long as it is understood that the region of larger rounded cells is rather inconspicuous, only about two cells wide and very near the surface. Younger portions of Berggren's specimens, and of a long series of matching cystocarpic plants from various parts of New Zealand show a well-defined region in the cortex where the rhizines are much more abundant than in the medulla; in fact the axis cross section before the midrib develops agrees better with Okamura's figures 5 and 7, Pl. 31, of two forms of *Gelidium amansii*, than with his figures of the Japanese species of *Pterocladia* closely related to *P. capillacea*.

P. pectinata, of which Lucas described a cystocarpic specimen (presumably unilocular) when he published the species (Lucas, 1931) is represented in the Laing Herbarium by a tetrasporic specimen (leg. Lucas). Cross sections of this would place it by Okamura's scheme definitely in *Gelidium;* indeed they agree quite well both with Okamura's description of those of *G. subcostatum* (1934, p. 52), and with sections made from a specimen of the same species, ex Herb. Michitaro Higashi, in the Laing Herbarium.

These observations indicate that the distribution of the rhizines in the axis is not a sufficient guide to the genus of a sterile specimen.

AXIS STRUCTURE AS A SPECIFIC CHARACTER.

Gardner (1927) recognised that this character might be important *within* the genus *Gelidium*, and he gives notes about the distribution of the rhizoidal filaments in seven out of the twelve entities he discusses. Feldmann and Hamel (*loc. cit.* p. 93) say, '' Dans certains cas, la disposition des rhizines peut être utilisée pour la distinction des espèces,'' for example in *G. attenuatum* the rhizines completely fill the spaces between the medullary cells of the central tissue, while in the superficially similar *G. sesquipedale* the central area is quite without rhizines. In *G. crinale*, on the other hand, which, like the two preceding species, has many rhizines in the inner cortex, rhizines may be either present or absent in the medulla.

It is a general experience that there is a certain range of structure within a single plant, and it is not always safe to draw conclusions from a single section. The rhizine proportion usually increases with the age of the part, which does not always vary as its size (often a narrow old part bears a broad young tip). A few sections from the middle of penultimate pinnules not too near the tip are the best guide, especially if considered with one from a primary or stout secondary rhachis.

Taking the younger parts, sections of New Zealand plants made in the present project fall easily into two groups: one with rhizines concentrated in the medulla, and one where the bulk of the rhizines is in the inner cortex, with the number in the medulla small at first,

but increasing with the age of the part. These distinctive cross sections are correlated with constant morphological differences and seem too good a specific character to be ignored. Conversely, it should be fair to assume that, in plants having essentially similar tissue arrangements, morphological differences need to be very clear-cut in order to be accepted as reliable bases for segregating species.

Pterocladia capillacea IN NEW ZEALAND.

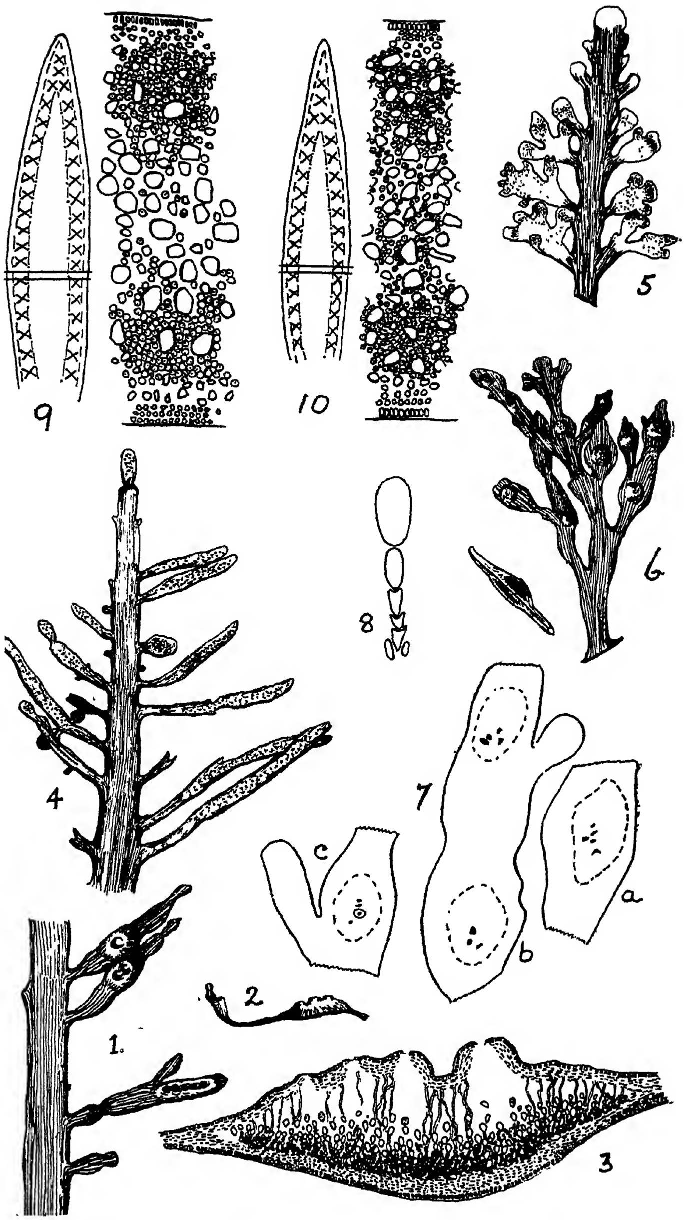
The New Zealand specimens examined can be divided without difficulty into two groups known commercially as *P. lucida* and *P. capillacea.*

The *P. capillacea* group is distinguished by small size (maximum about 30 cm. x 12 cm.), the cross section of the axis being oval in all parts except where it is occasionally almost circular, with the rhizines in young parts confined to the medullary region in the middle line (often forming a dumb-bell-shaped group in the whole T.S.), and, in the cystocarpic plant, by the usually single, strongly prominent, heavily rimmed carpostome.

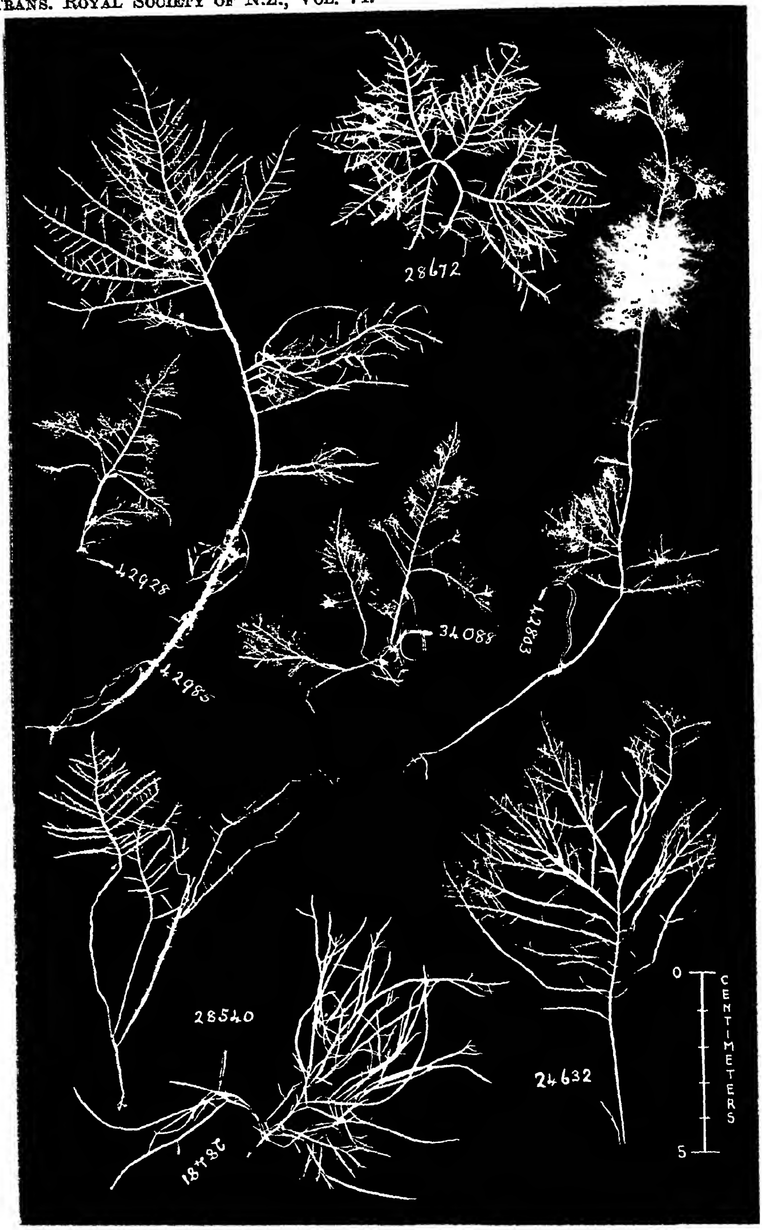
To this group belong also *P. nana, P. tenuis,* and *P. densa* of Okamura, who gives no very convincing character separating these from *P. capillacea. P. capillacea* is stated to be (p. 63) " less broader, often more irregularly branched than *P. tenuis,* and not constricted always to have pyramidal outline." Setchell and Gardner (1937) compare their very similar *G. (P.) okamuri* with *P. nana* but not with *P. capillacea.* Taylor's *P. americana* and *P. bartlettii,* which might otherwise be included in this group, are apparently distinct in that their tetrasporangial sori display clear V-shaped series.

In New Zealand material rather few plants are cystocarpic and this makes it difficult to eliminate the possibility that some might belong to species of *Gelidium* similar in form to *P. capillacea.* Among Okamura's illustrations, Pl. 16, Figs. 4 and 5 of *G. pacificum*, Pl. 19, Fig. 1 of *G. amansii* f. *typica*, Pl. 24, upper specimen of *G. subfastigiatum*, Pl. 28. Fig. 2 of *G. clavatum*, none of which represents a cystocarpic specimen, could all be fairly well matched among New Zealand *P. capillacea.* All New Zealand specimens sectioned, however, show in young parts rhizines more abundant in the medulla, with only an occasional one in the cortex, and therefore would be placed by Okamura in *Pterocladia.* It is perhaps worth noting that the rhizines are often very few; older parts of the axes are distinguished sometimes by the thickness of the cell walls, sometimes by an increase in number of rhizines, which in the main axes of the biggest plants may be evenly distributed throughout the whole cross section. The cells of the inner cortex are sometimes noticeably large and filled with floridean starch.

Gelidium corneum (Huds.) Lmx. has been recorded for New Zealand (see Laing, 1939, p. 141), and a number of specimens in the herbaria examined bear this name. None of the local specimens shows any good character to differentiate it from *P. capillacea.* Setchell (1931) published a photograph of what he considered to be the type specimen of *Fucus corneus* Huds., and concluded that *G. corneum* (Huds.) Lmx. in a strict sense was what Thuret later called *G. ses-*

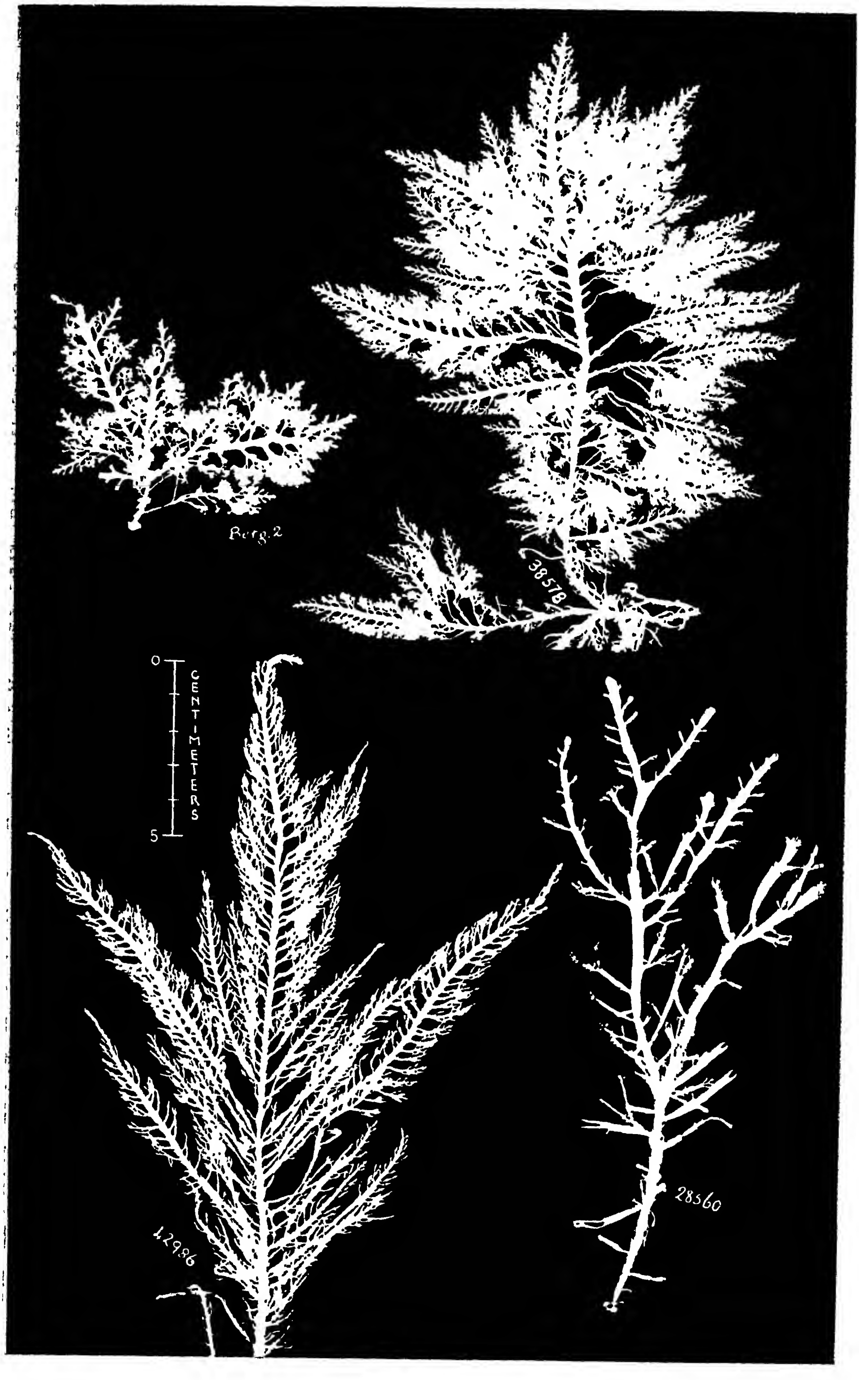


P. capillacea. Figs. 1–3 from Waiotemarama, June, 1944, No. 44818.
FIG. 1.—Twig with cystocarps showing 1, 2 and 5 ostioles.
FIG. 2.—Profile of pinnule with two cystocarps, one with one ostiole, one with three.
FIG. 3.—L.S. of cystocarp with 4 ostioles opening from one loculus.
FIG. 4.—From Opape, Bay of Plenty, February, 1941, No. 34054. Twig with tetrasporic sori.
P. lucida.—Figs. 5 and 6 from Aohanga, April, 1943. Fig. 5, twig with tetrasporic sori.
FIG. 6.—Twig with cystocarps; profile of one cystocarp.
FIG. 7.—Camera lucida outlines showing positions of ostioles on cystocarps; a and b from same plant, No. 28562, from O'Neill's Pt. Auck. W. coast, c from Geraldton, W. Australia.
FIG. 8.—Carpospore "chaplet" from 7c.
FIGS. 9 and 10.—T. S. pinnule, camera lucida outline and detail of median part. Fig. 9 from No. 38565. Fig. 10 from No. 42986.



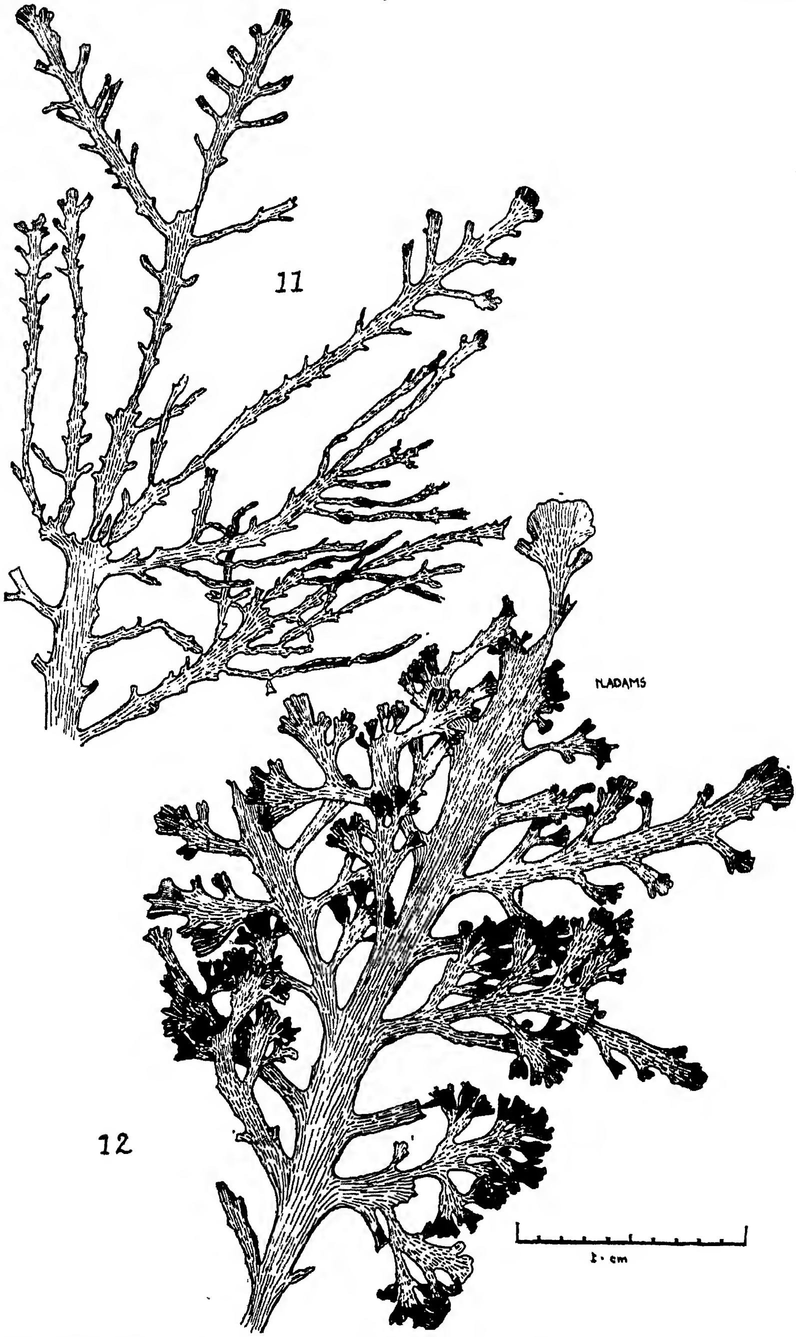
Specimens of *P. capillacea.*

No. 24632.—Waima Flat Reef, Tokomaru Bay, March, 1943, leg. Mrs. Tamati ♀.
No. 28481.—Takapuna, October, 1940, leg. L. B. Moore. "Pool form" sterile.
No. 28540.—The Mount, Tauranga (west end), October, 1940, leg. L. B. Moore. Deep high-level pool, sterile.
No. 28672.—Ohariu Bay, Wellington, November, 1940, leg. R. Mason, sterile.
No. 34088.—Te Kaha, Bay of Plenty, March, 1941, leg. L. B. Moore, ⊕.
No. 42803.—Campbell's Beach, Pihama, Taranaki, January, 1944, leg. L. B. Moore, sterile.
No. 42928.—Oeo Beach, Taranaki, January, 1944, leg. L. B. Moore, ♀.
No. 42985.—Ohiro Bay, Wellington, March, 1940, leg. L. B. Moore, ⊕.



Specimens of "robust" *P. lucida*. (See text.)

Specimens of several forms of *P. lucida*. (See text.)



Tetrasporic twigs of *P. lucida*, leg. Berggren, det. J. Agardh. Sori shown black.
FIG. 11.—"Littoralis" form from Hokianga, in Herb. Auck. Mus. (Berg. 1).
FIG. 12.—"Robust" form from Bay of Islands, in Herb. Dom. Mus. (Berg. 2).

[*To follow Plate 48.*]

quipedale. Feldmann and Hamel say (p. 127) "le *G. sesquipedale* ne contient de rhizines que dans la partie externe de la région médullaire; elles font totalement défaut au centre." No *Gelidium corneum*-like plant with that axis structure has been seen here, and it seems safe to conclude that *G. corneum* in that restricted sense at least is absent.

A small *Gelidium* from Bay of Islands has recently been distributed from the Herbarium of Victor W. Lindauer as No. 137 Algae Nova-Zelandicae Exsiccatae under the name *G. setchellii* Lindauer sp. nov., accompanied by a description. This seems to be quite distinct from the Californian *G. setchellii* Gardner published in 1927. It is of the same order of size as the local *P. capillacea,* but even without cystocarps it has clear differences in habit, in the vertically elongated holdfast with numerous irregularly-produced stolons, and in the cross section showing rhizines scattered through the medulla and densely crowded in a conspicuous cortical region.

Within a wide range of frond form, the axis structure of local *P. capillacea* is fairly uniform, and the cystocarps, wherever they turn up, are typically *Pterocladia*. Cystocarps have not been noticed strictly basal on a pinnule, but on some specimens an occasional one is terminal. Tetrasporic sori are usually much longer than wide (Pl. 45, Fig. 4) with young and old sporangia mixed; even in the young apical part there is no clear V-shaped series; dehiscence is acropetal, but not at all regular.

Though the forms of *P. capillacea,* here as elsewhere, are legion, it has proved beyond the powers of the present writer to sort them into definable groups. In fact, it seems unlikely that any two people (or even the same person at two different times) would make the same dispositions if asked to separate the several hundred specimens in the Botany Division Herbarium into matching lots, without leaving any over. The range of form and size is illustrated (Pl. 46) and the figures show also the typical, rather wide-angle branching, often regular and strictly pinnate to tri-pinnate, with well-defined smooth primary and secondary axes, the former often devoid of branches basally, and with pinnae and pinnules constricted near the point of insertion. Our specimens seem to have much in common with those examined from England, France (Bairritz, 9 Juillet, 1868, Bornet, ex Farlow Herbarium), Australia, Sandwich Is., Lord Howe Is., Norfolk Is., and Kermadec Is., and show no striking difference from a Japanese specimen ex Herb. Michitaro Higashi, Inatori, Izu, May, 1928, labelled *P. capillacea,* presumably the *P. tenuis* of Okamura. As Nos. 28540 and 42803* (Pl. 46) show, even parts of a single frond can exhibit contrasting shape, size, and habit of branching, demonstrating how unreliable these features are for systematic purposes. No more trustworthy basis for splitting has been found, and all the small *Pterocladia* of New Zealand with oval transverse section and predominantly medullary rhizines is regarded as belonging to one entity, presumably *P. capillacea* (Gmel.) Bornet et Thuret.

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* Unless otherwise stated numbers are those assigned to specimens in the herbarium of the Botany Division, Plant Research Bureau, Wellington.

Pterocladia lucida IN NEW ZEALAND.

The *P. lucida* group is distinguished by large size, ancipitous T.S. of all parts, with rhizines scattered or thickly clustered throughout the medulla but always more densely developed and straighter in the inner cortex (Pl. 45, Figs. 9 and 10); there is usually a strong midrib in older axes; the carpostomes are slightly sunken, never raised on a projection, faintly rimmed, and usually multiple in each cystocarp with no regular arrangement; tetrasporangia often show a V-arrangement near the retuse apex of the growing sorus. The complex holdfast, described and figured by Moore (1944) seems to be a very stable character, contrasting strongly with the very simple attachment organs of *P. capillacea*.

The material examined exhibiting these common features falls into several sets, linked by intermediates, and all obviously much more closely related to one another than any of them is to *P. capillacea* or to the Australian *P. pectinata*.

Harvey (1863), in discussing the variability of *P. lucida*, suggests the possibility of difference between Australian and New Zealand specimens, but the few Australian plants available here show a range of forms similar to ours, though sections were inconclusive. The point can be decided only when more information is available about the genus in Australia.

Mrs. Valerie May Jones, of the Fisheries Section of the Australian Council of Scientific and Industrial Research, mentions in a letter (5th May, 1944) a specimen in the Sydney Herbarium called *P. pectinata* from East Cape, New Zealand. The present writer has made collections from within a few miles of East Cape, on either side, and has met with nothing to correspond either with the Lucas *P. pectinata* specimen in the Laing Herbarium, or with Mrs. Jones's brief description of the New Zealand specimen in the Sydney Herbarium.

Agardh (1876, p. 545) proposed two rather ill-defined varieties, α and β, of *P. lucida*, but did not quote specimens or localities for either. He had probably by this time seen Berggren's specimens collected in New Zealand in 1874–75, amongst the fragments of which that have returned to New Zealand herbaria there are several forms represented, but it is not easy to relate the varietal diagnoses to these.

Laing (1939) says "apparently common in at least two forms." Their status is of economic importance in that they behave rather differently in agar processing. It would be interesting to see to what extent such differences depend on proportion of rhizine to cellular tissue, a ratio which varies from part to part of one plant but is apparently higher in the more robust forms.

Two difficulties arise—(1) that of defining sharp limits between forms, and (2) that of deciding to which the name *lucida* really belongs if there are two or more species involved. The only feasible course seems to be to illustrate the chief New Zealand forms (this has not hitherto been done for *P. lucida* in any part of its range) and to distinguish, as a matter of convenience, those kinds which, though of uncertain status, have some practical significance.

P. lucida Forms.

Robust Form (Pl. 47).

No. 38578. From near Table Cape, Mah'a Peninsula, leg. L. B. Moore, December, 1942. Tetrasporic.

This broad, robust form, often more richly branched than in this specimen, is the commonest east coast form, growing in rough places and to a depth of some feet below low tide mark. Similar specimens have been received from Chatham Is. The frond shape matches fairly well that shown in Turner's figure (t. 238) of *Fucus lucidus.* The tetrasporic sori (Pl. 45, Fig. 5) are on distinct reproductive branchlets, broad in comparison to length, and often lobed like those figured by Turner. The biggest plant seen is well over a metre long.

Specimens from Maroubra Bay, N.S.W. ⊕ (Laing Herb., leg. Lucas), from Port Phillip, Australia (leg. F. von Müller, ex Herb. W. G. Farlow), and from Lord Howe Is. ⊕ (Auck. Mus. Herb., leg. J. D. McComish) are similar to this form except that they are of more membranous texture.

A series of odd little plants under collecting No. 312, Herb. V. W. Lindauer, grew epiphytically on Durvillea holdfast or on barnacles at the base of the holdfast, through holes in the upper surface of which they protruded. Several have standard *P. lucida* cystocarps and the T.S. of the axis shows nothing novel. Branching is almost inhibited in some cases, but in others it is of a pattern that can be matched on larger and more "normal" looking plants from other places. In my opinion these are just plants of the robust form modified by their strange growing place.

Berg. 2. From Bay of Islands, leg. Berggren, Dominion Museum Herbarium. Tetrasporic. This fragment agrees well with No. 38578. Details are shown in a sketch (Pl. 49, Fig. 12).

No. 42986. From Cape Turnagain, leg. U. and P. Herrick, 1930, Auck. Mus. Herb. Cystocarpic.

Fronds with short, regular fine pinnules have come also from Anaura Bay (No. 38591 ⊕) further north on the east coast, and others, not quite so regular, from a number of localities. Though these look rather distinct, they are probably just a casual aspect of the common robust form. The typical *P. lucida* T.S. (Pl. 45, Fig. 10) distinguishes this from *P. pectinata.* No tetrasporangial branchlets like the sharply-differentiated, often terminal ones in the Lucas specimen of *P. pectinata* have been seen here.

No. 28560. From O'Neill's Pt., Te Henga, Auckland West Coast, leg. L. B. Moore, October, 1940. Tetrasporic.

A small plant of a stout, elongated kind, sparsely and strictly branched, with main axes broad throughout, and with clearly-defined tetrasporic pinnules often, but not uniformly in all parts of one plant, in regular lateral rows.

Plants of this shape, which are found almost exclusively on the very exposed rocks of the west coast, appear to be simply rougher water representatives of the common robust form; plants like No. 38578 grow nearby in more sheltered spots.

"Littoralis" Form (Pl. 48).

No. 38565. From Waihau Bay, Cape Runaway, leg. P. Hauraki, November, 1942. Tetrasporic. (Pl. 45, Fig. 9).

This finely branched form has been called "*littoralis*" (Moore, 1944). It is characterised by the narrowness of the pinnules which frequently break off leaving ragged stumps. Adventitious haptera on ultimate pinnules are not uncommon. The tetrasporic sori are typically very narrow-linear, not lobed, and not on clearly-differentiated tetrasporic pinnules.

This form is widely distributed on the east coast, and has been found in pools growing alongside the robust form, so that the two are perhaps unlikely to be habitat forms only. It comes up freely in the drift. Localities where it is abundant or even predominant in collections are Aohanga, Wellington, Kaikoura, and occasionally in the Bay of Plenty. These fine fronds introduce difficulties in processing, and the resultant agar differs from that from stouter plants.

Berg. 1. From Hokianga, leg. Berggren, det. J. Agardh, Auck. Mus. Herb., ex Herb. Bot. Garden, Gothenburg. Labelled "*Pterocladia lucida* (Fl. Nov. Zel.)" Tetrasporic.

This fragment and also a whole plant in Herb. Dominion Museum, collected at Bay of Islands by Berggren are of the "*littoralis*" kind. Pl. 49, Fig. 11 shows the slender tetrasporic sori for comparison with the broad ones of the robust form. Two Australian specimens in the Laing Herbarium might be grouped here, one, cystocarpic, from Geraldton, W.A., and one, sterile, from Investigator Strait. Nos. 234, 690, 1004 and 1139, Herb. V. W. Linduaer, all from Bay of Islands, belong here. An extremely attenuated state is seen in a specimen from Kennedy Bay, Coromandel, in the Auckland Museum Herbarium. A similar one from Lyall Bay, No. 785, Herb. R. M. Laing, has many haptera near pinnule tips.

Delicate Form (Pl. 48).

No. 24633. From Omapere, Hokianga, leg. Mrs. Caddell, August, 1942. Antheridial.

A similar deltoid fine-textured frond with main axes broad to the tips is an antheridial one, also from Hokianga, leg. Berggren (Auckland Museum Herbarium), and this form is represented by a considerable suite of specimens from Hokianga in the Botany Division Herbarium. A sterile specimen from Norfolk Is. (No. 39267) with a *P. lucida* T.S. matches No. 24633 except that it is much smaller.

This comparatively delicate form shows considerable range of shape, the whole frond sometimes being quite narrow like one of the pinnules of No. 24633. The tetrasporic sorus is usually three to four times as long as wide, mostly simple, but it may be lobed. The plant is flaccid and almost clinging when wet, and has a different "handle" from any other kind; no corresponding difference in the tissues or their arrangement could be traced, the T.S. showing all the essential features of *P. lucida*.

It grows in large quantities inside the Hokianga Harbour, which forms an exception to the rule that in New Zealand *Pterocladia* nearly always grows on an open coast. Here, on gently sloping papa rock, *Pterocladia* beds extend as far as Pakanae, about five miles in from the Heads along the southern shore of the harbour. In one year some

11,000lb of dry *Pterocladia* was sold from this Pakanae-Opononi-Omapere district, and the greater part of this would be of the delicate form.

Tetrasporic plants from Great Barrier Is. are intermediate between this and "*littoralis*," as are both antheridial and cystocarpic plants from Cook Strait and from Tauranga.

Indeterminate Forms (Pl. 48).

No. 42987. From Kaikoura, drift, leg. L. B. Moore, August, 1943. Tetrasporic.

This form, abundant at Kaikoura and Wellington and probably elsewhere, is one of the many intermediates between "*littoralis*" and the common robust form, and illustrates the difficulty in finding a sharp dividing line between these two that, in the extreme case, look so different. One such plant, from Lyall Bay, leg. Berggren, is in the Dominion Museum Herbarium.

Poor Knights Form (Pl. 48).

No. 41, Auckland Museum Herbarium. From northern island of Poor Knights group, leg. L. M. Cranwell and L. B. Moore, February, 1937. Tetrasporic.

This form is perhaps deserving of varietal rank, since it differs widely from the robust form that grows abundantly around this small island. A good and fairly uniform series was collected (Sheets 34–41, 64, 174, Herb. Auck. Mus.), sufficient to show that this is not a chance abnormality. At its best development there this plant has long primary axes and is more closely and bi- to tri-pinnately branched distally than is this medium-sized specimen. The sides of the flat axes are not lacerated; the holdfast and T.S. are of the *P. lucida* pattern. All the herbarium specimens are tetrasporic with broad, delicate blunt-ended sori like those of robust *P. lucida*. In the absence of cystocarps this may be a *Gelidium*, but the resemblances to *P. lucida* are strong.

Conclusions about P. lucida.

It will be seen that of the five forms distinguished here, all but the Poor Knights one are represented in Berggren's collection, probably all identified by J. Agardh, while three of Berggren's four can be matched outside New Zealand. The robust form predominates greatly in most commercial collections, and is preferred by agar manufacturers. Several points indicate that "*littoralis*" may be genetically distinct, but the intermediates are an obstacle to describing it as a variety.

The ability of a single plant to produce new branchlets from broken surfaces, the inconstancy of size and branching characters within one individual, the occurrence of certain forms only in certain types of habitat, all suggest that epharmonic response is highly developed. The features in which these plants differ from *P. capillacea*, seen in holdfast, carpostome, outline of cross section and arrangement of rhizines are just those that remain uniform throughout the long series of specimens examined. They are regarded as indicating genetically distinct entities. On the other hand, there is no obvious anatomical or morphological feature that would make it impossible for, for instance, a West Coast plant to produce twigs

of the Omapere form, or vice versa, if the appropriate transplants were made. The differences are not greater than those between the limicolous form of *Fucus vesiculosus* and saxicolous plants of which pieces were shown by Baker and Bohling (1916) to be capable of sprouting vegetatively when pinned down in the marsh.

On the available evidence it seems advisable to retain all these forms under the one species, and this is considered to be *P. lucida* (R.Br.) J.Ag., on the assumption that Agardh's description of the internal structure applied to older parts of axes only. It is hoped that this account of the common features and differences may be of use in placing new variants that may turn up, and also that the discussion may facilitate the comparison of our plants with those of Australia and the South-West Pacific generally.

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Transactions of the Royal Society of New Zealand, Vol. 74, Part IV, pp. 343–358, 5 Text Figs.

A Comparative Account of the Vascular System of Certain Rajiform Fishes.

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Introduction.

Having investigated *Squatina squatina*, one of us (B. J. M.) began, in England, to study the vascular system in various species of *Raja*. In New Zealand a start was made also on the dissection of the highly specialised Blind Numb Fish *Typhlonarke aysoni*, and the work was then taken over by M. L. P., who is responsible for the drawings and descriptions in this paper, and most of the dissections upon which they are based. The species of ray whose vascular system has been most fully described is *R. nasuta*, studied by T. J. Parker in this department towards the end of last century. Dissections were made of this species as a typical ray, and single specimens of the Stingray, *Bathytoshia brevicaudata*, and the Electric Ray *Notastrape fairchildi* were also dissected. The names used here are those given by Whitley (1940). Among the specimens of *Typhlonarke* dissected, some appeared to differ externally from *T. aysoni* and probably belong to another species, but no differences in the vascular system were observed.

The order Selachii is divided by Goodrich (1930) as follows:

Group 1. Notidani.
Group 2. A. Suborder Heterodonti.
B. (a) Suborder Scylloidei.
(b) Suborder Squaliformes.
(c) Suborder Rajiformes.
Sec. 1. Squatinoidei.
Sec. 2. Rhinoraji.
Sec. 3. Centrobatoidei.
Sec. 4. Torpedinoidei.

Detailed studies of Selachian vascular systems are not very numerous, but members of the Notidani have been described by Daniel (1928), of the Scylloidei by Parker (1886), O'Donoghue (1914), and Marples (1936, 1), and of the Squaliformes by O'Donoghue (1928). Marples (1936, 2) described the vascular system of *Squatina* and gave reasons for its removal from the Rajiformes. No complete description of members of the Rajiform groups appears to exist, the most complete being that of *R. nasuta* by Parker (1884), while the posterior region of *R. erinacea* was described by Rand and Ulrich (1905) and Daniel (1928) gave certain details of *Dasyatis dipterura*, a stingray belonging to the Centrobatoidei. The present paper is an attempt to add to our knowledge of the vascular system of the Rajiformes, but a great deal of interesting work remains to be done when material is available, especially among

the stingrays. It may be mentioned that Goodrich (1909) suggests a connection between the Rhinobatidae, Pristidae and Rajidae, but a separate origin from the primitive Rajiform stock for the Torpedinidae, Trygonidae and Myliobatidae, with the Torpedinidae nearest to the Rajidae.

Typhlonarke has such a peculiarly modified skeleton that a brief description is desirable and the general disposition of the parts is shown in Fig. 1. It is oval in shape, with a very abbreviated tail and small mouth. The pectoral fins arise very far back and the pectoral and pelvic girdles overlap considerably. Between the pectoral fins and the anterior part of the body lie the large electric organs. Goodrich (1909) states that in the Torpedinidae the two halves of the pectoral girdle are not firmly fused together, but this is not true of *Typhlonarke*.

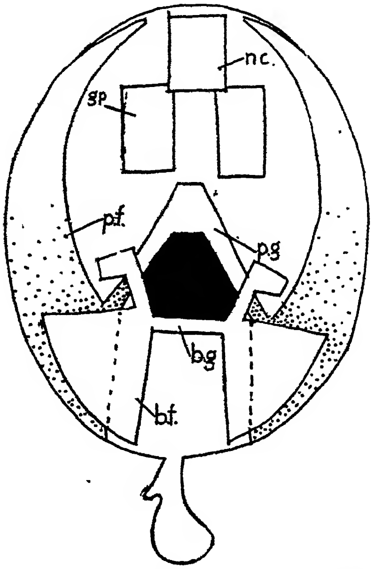


FIGURE 1.—Diagram showing the structure of *Typhlonarke*. (For explanation of letters see end of paper.)

THE HEART.

The sinus venosus is a triangular chamber into which run the ductus Cuvieri of the right and left sides. It opens into the atrium, which is a large, thin-walled chamber. This lies dorsal to the ventricle into which it opens on the left side. The ventricle has very thick muscular walls and is asymmetrical, being rather larger on the left side than on the right. It runs forward, narrowing into the conus arteriosus. The valves of the conus have been used to a certain extent in classification. In the most primitive sharks there are three longitudinal rows of four valves. In most sharks this number is decreased, while in rays it is increased, at least this is the general supposition. But of the animals examined, *R. nasuta*, the stingray and Torpedo, all resemble the primitive sharks in having three long rows each containing four valves. In *Typhlonarke* one of the rows

contains three valves, the others four. It seems, therefore, that an increase in the number of valves is by no means universal among the rays.

The Ventral Aorta.

The ventral aorta arises from the conus arteriosus and runs forward ventrally in the midline. Normally the ventral aorta runs forward to the level of the first gill-slit before bifurcating (Fig. 3, A and C), but in Torpedo (Fig. 3, B) it is shorter and bifurcates on a level with the second gill-slit.

The Afferent Branchial Arteries.

In *Typhlonarke* (Fig. 3, C) almost immediately after leaving the conus, two stout branches are given off symmetrically from the ventral aorta. These redivide into two, the posterior ones being the fifth afferent arteries. At once the anterior branches redivide forming the third and fourth afferent arteries. On a level with the first gill-slit the ventral aorta bifurcates into the two innominate arteries, which divide to form the first and second afferent arteries. The afferent arteries are dorsal to the jugular sinus.

The three species of Rajidae examined, *R. nasuta, R. clavata* and *R. batis,* are all similar to *Typhlonarke* in the origin of their afferent arteries, while in Torpedo the common stem of the three posterior ones is quite short (Fig. 3, B). The Stingray, however, has the three posterior arteries arising separately though close together from the ventral aorta. This is figured also by Daniel (p. 178) for *D. dipterura.* In this respect the stingrays resemble the sharks, where the third, fourth and fifth afferent arteries never arise from the ventral aorta by a common stem, though the fourth and fifth may do so.

The Efferent Branchial Arteries. (Fig. 2.)

In *Typhlonarke,* as in other Selachians (Fig. 2, C) the efferent branchial arteries form complete loops around the first four gill-slits. The fifth gill-slit has only an anterior hemibranch, and so an efferent artery only upon the anterior side. These loops are all connected by commissural arteries which traverse the gill-bars. From these commissural arteries arise the arteries which supply the electric organ (e.a.). The most anterior vessel to this organ (e.,a.,) arises from the hyoidean epibranchial artery. From the ventral ends of the efferent loops arise the hypobranchial arteries (Fig. 3, C), while from their dorsal ends the epibranchial arteries (ef.a.) originate.

This arrangement is common to all the fishes examined, except for the arteries to the electric organ, which are possessed by *Typhlonarke* and Torpedo only.

The Dorsal Aorta. (Fig. 2.)

The dorsal aorta runs along the median axis of the body, dorsal to the gut and ventral to the spinal column. Its anterior end, the paired internal carotid arteries, pierces the brain case, while its posterior part supplies the tail as the caudal artery, which lies in the haemal canal of the caudal vertebrae.

In sharks, there are anteriorly two lateral dorsal aortae, which receive the hyoidean epibranchial arteries and unite to form the internal carotid artery. In none of the fishes examined were there any signs of the lateral dorsal aortae extending forward to join

the hyoidean epibranchial arteries as in sharks, though the common bases of the first and second epibranchial arteries of *Raja* and

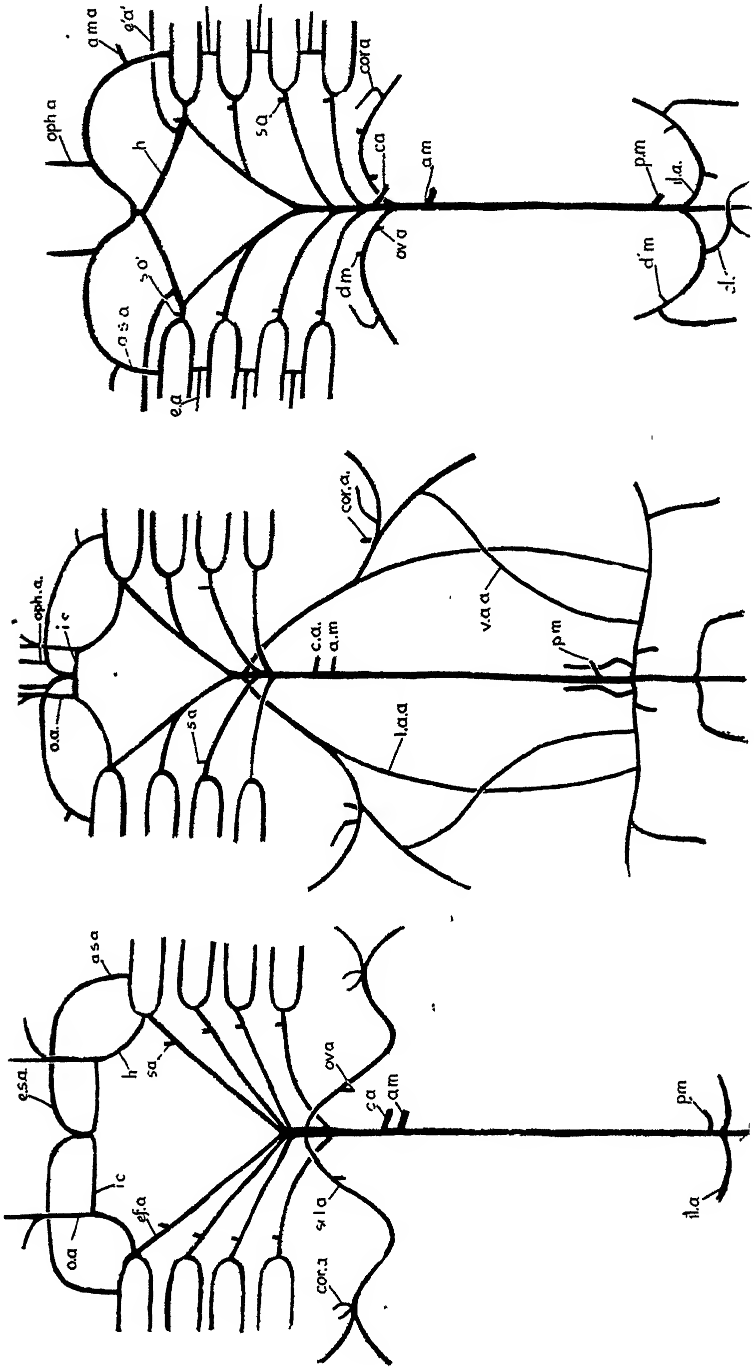


FIGURE 2.

A, Stingray. B, *Raja nasuta.* C, *Typhlonarke.*

Dorsal view of arterial system, omitting the hypobranchial and afferent arteries.

(For explanation of letters see end of paper.)

Typhlonarke on each side (Fig. 2, B and C) are presumably lateral dorsal aortae. Absence or interruption of the lateral dorsal aortae seems characteristic of the rays, while these vessels are complete in the sharks (Daniel) and in *Squatina* (Marples).

In *Typhlonarke* (Fig. 2, C) the dorsal aorta bifurcates anteriorly into the common stems of the first and second epibranchial arteries. The third and fourth enter the dorsal aorta separately. Just posterior to the fourth epibranchial arteries the coeliac artery (c), then the subclavians (scl.a.) and then the anterior mesenteric (a.m.) arteries are given off. The posterior mesenteric (p.m.) and iliac arteries (i.a.) are given off much further back.

In the stingray (Fig. 2, A) the four epibranchial arteries enter the dorsal aorta separately, and the subclavian arteries arise posterior to the third epibranchial and anterior to the fourth. The coeliac and anterior mesenteric arteries arise posterior to the fourth epibranchial artery. In *R. nasuta* (Fig. 2, B) the first and second epibranchial arteries have a common stem as in *Typhlonarke*, but the subclavian arteries arise posterior to this common stem, and anterior to the third epibranchial arteries. *Typhlonarke* is peculiar in that the subclavian arteries arise very far back, not only posterior to the last epibranchial but to the coeliac artery as well. This may be correlated with the abnormally posterior position of the base of the pectoral fins.

In *Typhlonarke, Torpedo* and the Rajidae, the first and second epibranchial arteries enter the dorsal aorta by a common stem. This condition is not found in sharks, which in this respect are like the stingrays. In these, the first three epibranchial arteries enter the dorsal aorta very close together, the fourth much further back.

In *Typhlonarke,* close to the efferent loops, a branch (s.a.) is given off from each epibranchial artery to supply the dorsal superficial musculature of the pharynx and the gill flaps. Similar arteries were found in the Stingray accompanying the cutaneous veins (Fig. 4, A, c.v.) which empty into the anterior cardinal sinus. In *R. nasuta* only one superficial artery is present, arising from the third epibranchial artery and giving an anterior and a posterior branch supplying the superficial musculature.

ARTERIES OF THE HEAD. (Fig. 2.)

In *Typhlonarke* the hyoidean epibranchial artery (h.) arises from the first efferent branchial loop and passes forward to join its fellow from the opposite side and enter the brain case as the internal carotid artery. Just after leaving the efferent loop it gives rise to a superficial artery (s.a.). This artery divides into three branches, one of which goes to the superficial spiracular region, another to the muscles about the otic capsule, and the third to the dorsal surfaces of the lateral rostral cartilages. Just anterior to the superficial artery another branch arises (e.,a.,) which runs to the electric organ. This artery is not similar morphologically to the other arteries supplying the electric organ, for if it were it would arise from the afferent spiracular artery (a.s.a.) which corresponds to the commissural arteries between the efferent loops. Nor is it homologous with the orbital artery, which passes anterior to the spiracle, while this artery

is behind it. The orbital artery is absent in *Typhlonarke*. This fish is blind, and the eyes are reduced to small remnants, but as the orbital artery usually supplies a considerable part of the anterior region of the head as well as the eye muscles, this would not seem to account for its absence. In *Torpedo, R. nasuta* and the Stingray, the hyoidean epibranchial artery gives rise to an orbital artery (o.a.) which passes ventral to the brain case, and in the orbit runs dorsal to the efferent spiracular artery (e.s.a.) but ventral to nerves V and VII, to which it runs parallel. In front of the eye it divides into two, the median branch supplying the ventral surface of the rostral cartilages and giving a branch to the roof of the mouth, the lateral one turning posteriorly to supply the muscles of the upper jaw.

After the orbital artery has been given off, the two vessels, now usually known as the internal carotid arteries and representing morphologically the anterior ends of the lateral dorsal aortae, proceed anteriorly and unite in the middle line to pass through a foramen on the floor of the brain case. Inside, a branch is given dorsally which divides into anterior and posterior cerebral arteries. The posterior cerebral arteries pass along the posterior region of the brain to the spinal cord and are there augmented by branches of the segmental arteries.

Spiracular Arteries. (Fig. 2.)

These are often called the pseudobranchial arteries, but, as a pseudobranch is not always present, spiracular is perhaps the better term. In *Typhlonarke* the afferent spiracular artery (a.s.a.) passes median to the pseudohyal and lateral to the hyomandibular cartilage. Before reaching the spiracle, it gives off a branch (a.m.a.) which possibly represents the afferent mandibular artery, the mandibular arterial arch being interrupted in its lower half in all elasmobranchs except *Squatina squatina* and *Callorhynchus antarcticus*. This branch is also present in *Torpedo* and *Raja*, but as in *Typhlonarke*, there is no ventral connection. The efferent spiracular artery (e.s.a.) is in *Typhlonarke* a very fine vessel which leaves the spiracle, passes through the cartilage of the brain case, and joins the internal carotid artery, having given off the ophthalmic artery (oph.a.) before passing through the cartilage. This artery gives a branch to supply the muscles of the lower jaw and proceeds forward to supply the rostral cartilages.

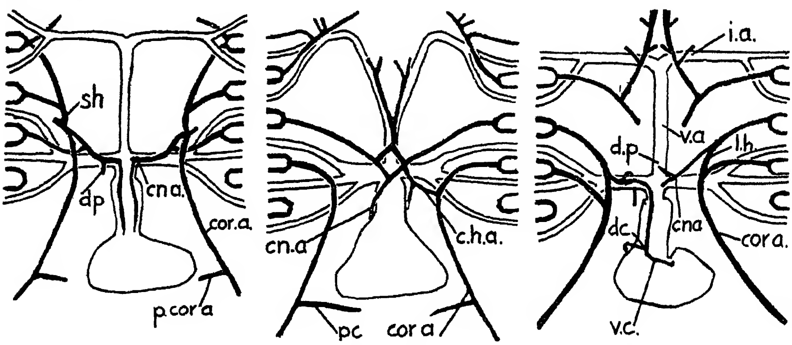
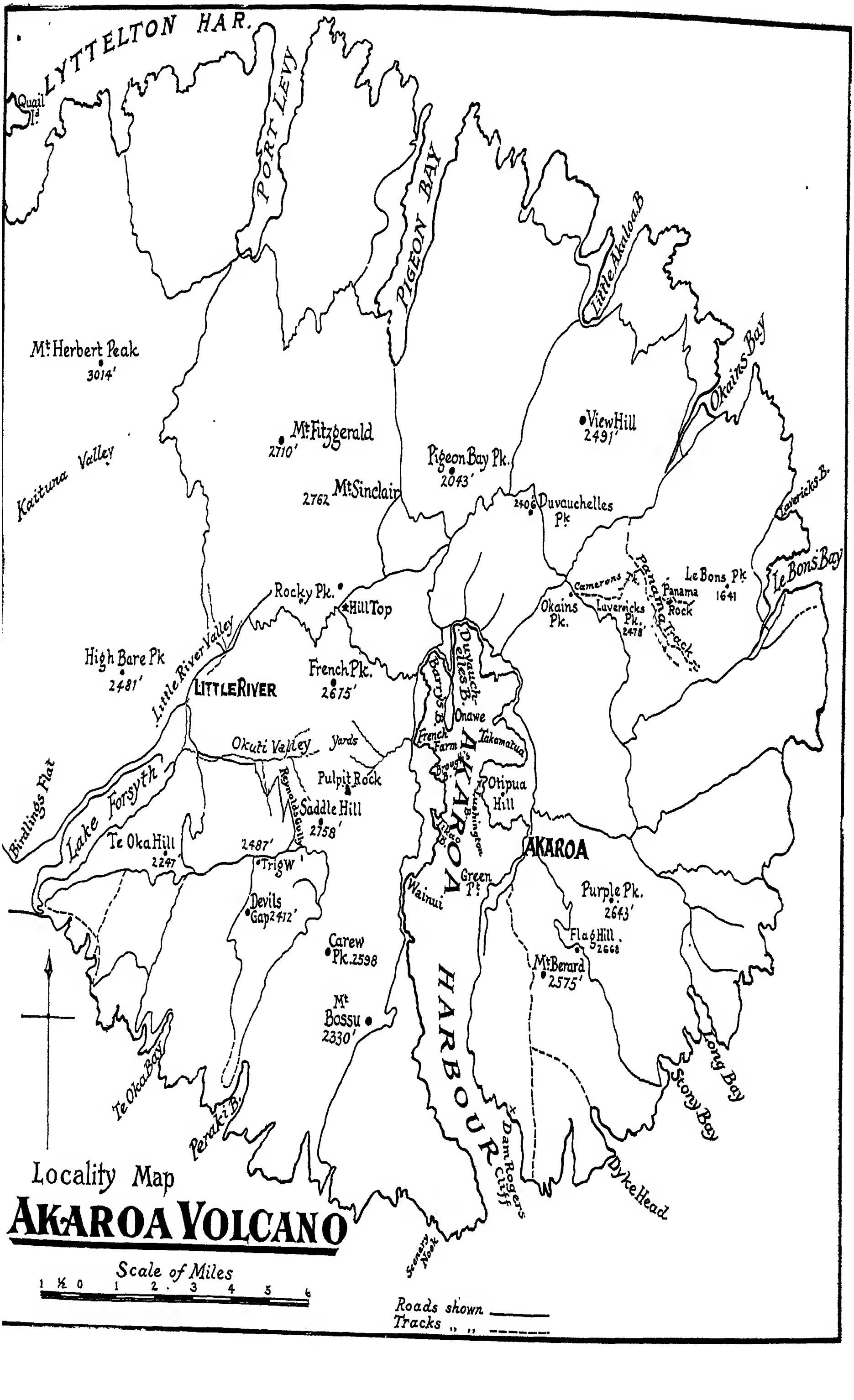


Figure 3.—A, *Raja nasuta*. B, *Torpedo*. C, *Typhlonarke*. Hypobranchial and afferent arteries from the ventral side. (For explanation of letters see end of paper.)


LYTTELTON HAR.
Quail Id.
PORT LEVY
PIGEON BAY
Little Akaloa B.
Okains Bay
Mt. Herbert Peak 3014'
Mt. Fitzgerald 2710'
Kaituna Valley
Pigeon Bay Pk. 2043'
View Hill 2491'
2762 Mt. Sinclair
2406 Duvauchelles Pk.
Lavericks B.
Le Bons Bay
Le Bons Pk. 1641
Panama Track
Camerons Pk.
Panama Rock
Luvericks Pk. 2478'
Okains Pk.
Rocky Pk.
Hill Top
High Bare Pk 2481'
Little River Valley
LITTLE RIVER
French Pk. 2675'
Duvauchelles B.
Barrys B.
Onawe
French Farm
Takamatua
Okuti Valley
Yards
Pulpit Rock
Brough's B.
Otipua Hill
Birdlings Flat
Lake Forsyth
Reynolds Gully
Saddle Hill 2758'
Te Oka Hill 2247'
2487'
Trig W
AKAROA HARBOUR
Lushington
AKAROA
Green Pt.
Purple Pk. 2643'
Devils Gap 2412'
Wainui
Carew Pk. 2598
Flag Hill 2668
Mt. Berard 2575'
Mt. Bossu 2330'
Long Bay
Stony Bay
Te Oka Bay
Peraki B.
Dan Rogers Cliff
Dyke Head
Scenery Nook
Locality Map
AKAROA VOLCANO
Scale of Miles
1 ½ 0 1 2 3 4 5 6
Roads shown
Tracks " "

In *R. nasuta* (Fig. 2, B) the afferent spiracular artery proceeds on the median side of the pseudohyal cartilage, lateral to the hyomandibular, and gives off the afferent mandibular artery before reaching the spiracle. From here the efferent spiracular artery passes across the floor of the orbit, ventral to the orbital artery. Median to it, it gives off the ophthalmic artery which runs along the medio-dorsal surface of nerves V and VII, and supplies the eye.

THE HYPOBRANCHIAL ARTERIES. (Figs. 3 and 5.)

The hypobranchial arteries arise from the ventral ends of the efferent loops and form a complicated system of vessels on the ventral wall of the pharynx. They supply the heart by the coronary arteries, and are joined to the subclavian arteries (s.cl.a.) by the coracoid arteries (cor.a.). In *Typhlonarke* the first hypobranchial artery arises from the first efferent loop and runs medio-posteriorly, ventral to the afferent arteries. It divides into two arteries, both supplying the thyroid gland. The second, third and even the fourth hypobranchial arteries may unite and run backwards as the lateral hypobranchial artery (l.h., Figs. 3 and 5). The second does not always join the lateral hypobranchial. The first gives rise to a superficial artery (Fig. 5, s.h. 1) laterally which divides to supply the ventral musculature of the gill flaps and the pharynx. A similar one arises from the second hypobranchial (s.h. 2), but the third superficial artery (s.h. 3) arises, not from the third hypobranchial but from the lateral hypobranchial. It supplies the last three gill flaps. The coronary artery (Fig. 3, C, cn.a.) arises from the median side of the lateral hypobranchial and runs along the common stem of the three posterior afferent arteries. On the left side, the coronary artery, before reaching the ventral aorta gives off a dorsal pericardial branch (d.p.). On the ventral aorta it turns posteriorly at right angles and runs along the conus to the ventricle. On this it divides into a ventral coronary artery (v.c.a.) and a dorsal coronary artery (d.c.a.). The lateral hypobranchial artery gives a branch to the ventral wall of the pericardium, but there is no posterior coronary artery. The lateral hypobranchial continues backwards as the coracoid artery (cor., Figs. 3 and 5), which passes dorsal to the coracoid cartilage and joins the subclavian artery.

In Torpedo (Fig. 3, B) as in *Typhlonarke* the first hypobranchial is not connected to the second, but it is the second which supplies the thyroid gland. The second hypobranchial runs towards the ventral aorta, sends two branches anteriorly, and then is joined to the third hypobranchial by a commissural vessel (c.h.a.). This was found on one side only. The coronaries arise one from the commissural hypobranchial and the other from the base of a square formed by the arteries on the ventral aorta. The third hypobranchial sweeps back as the coracoid artery dorsal to the coracoid cartilage. Owing to the posterior part of the specimen being destroyed it was not possible to locate a connection with the subclavian artery, though one no doubt exists.

In *Typhlonarke* the lateral hypobranchial artery is ventral to the afferent arteries. This is not the case in the sharks, where this vessel is dorsal to the afferent arteries and median hypobranchials are

present ventral to the afferent system, as in *M. antarcticus, M. canis,* and *S. squatina.* In *Hexanchus corinus* the median hypobranchial arteries are dorsal to the afferent arteries but the coracoid arteries have a common median stem on the ventral side of the ventral aorta (Daniel, pp. 164 and 178). It seems possible that the ventrally situated, so-called "lateral hypobranchial arteries" of Raja and the median hypobranchial arteries more or less fused on the ventral side of the ventral aorta of *Mustelus*, are homologous vessels. The median hypobranchial arteries of *Dasyatis* and *Squatina* are more or less intermediate in position. The coracoid arteries always arise from the ventral vessel whether medially or laterally situated. Of course it it always possible that commissural vessels of the hypobranchial system were formed surrounding an afferent artery and then that the dorsal portion was lost. This would account for the condition found in *R. nasuta* and *R. clavata.* In these the lateral hypobranchial artery connects up the hypobranchials of the first four gill slits. It runs dorsal to the second afferent artery and ventral to the others. The superficial musculature is supplied by a branch arising from the lateral hypobranchial about the level of the third gill slit. Daniel (p. 178) states that the lateral hypobranchial is incomplete in *R. clavata,* so there appears to be variation in this arrangement.

PAIRED ARTERIES. (Fig. 2.)

. In *Typhlonarke* the subclavian arteries arise symmetrically posterior to the fourth epibranchial arteries. An ovarian branch (ov.) is given off, running posteriorly, parallel to the dorsal aorta, then another branch runs to the dorsal musculature (d.m.). The coracoid artery (cor.) joins the subclavian artery after passing dorsal to the coracoid cartilage and arising from the hypobranchial system as described above. In *Typhlonarke* the coracoid artery is very fine in comparison with the wide vessel in *R. nasuta.* In *R. nasuta* the subclavian artery receives the coracoid artery at a point just median and ventral to the division into the propterygial and metapterygial arteries. From the propterygial artery about two centimeters from where the subclavian divides, a branch passes round dorsally to the anterior side of the propterygial cartilage. A ventral abdominal branch (Fig. 2, B, v.a.a.) from the metapterygial artery runs medio-posteriorly on the dorsal side of the metapterygial cartilage along the ventral body wall to join the iliac artery. From the subclavian there arises the lateral abdominal artery (l.a.a.), which passes along the side of the body cavity and joins the femoral artery lateral to the ventral abdominal artery.

In *Typhlonarke* the iliac arteries have cloacal arteries arising from them, of which the right one is the larger. A dorsal artery (d.m.) supplies the dorsal muscles, and the iliac artery then supplies the fin. A branch of fair size is given to the anterior basal cartilage and also supplies the first few radials. The remainder of the radials are supplied by an artery which proceeds backwards, dorsal to the radials and lateral to the basipterygium.

In *R. nasuta* (Fig. 2, B) two spermatic arteries arise median to the cloacal arteries and pass anteriorly. After receiving the ventral abdominal and then the lateral abdominal arteries, the iliac artery divides in the fin. In *R. montagui* a branch from near the base of

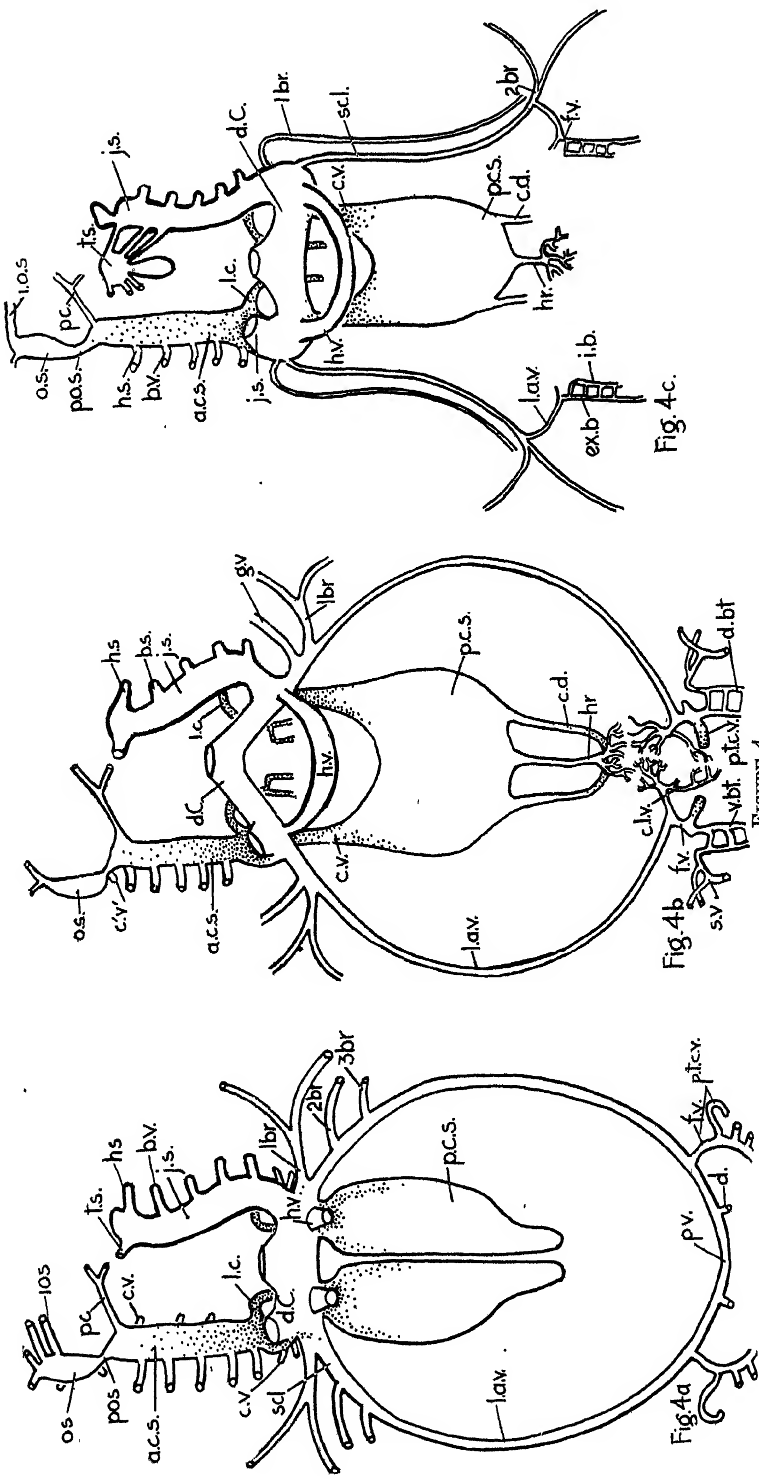


FIGURE 4

A, Stingray. B, *Raja nasuta.* C, *Typhlonarke.*

Venous system, omitting the renal and hepatic portal systems.
(For explanation of letters see end of paper.)

the iliac artery runs forward along the median side of the kidney, sends a branch to the posterior fused portion of the oviducts and anastomoses with two large segmental arteries which leave the dorsal aorta near the anterior end of the kidney. The oviducal gland and anterior part of the oviducts are supplied by branches of three large segmental arteries arising anterior to the kidneys.

THE ANTERIOR CARDINAL SINUS. (Fig. 4.)

In *Typhlonarke* (Fig. 4, C) the anterior cardinal sinus (a.c.s.) stretches from the back of the auditory capsule to the end of the ductus Cuvieri (d.c.). Anteriorly it receives the hyoidean sinus (h.s.), which connects it to the jugular sinus (j.s.), the post-orbital sinus (p.o.s.) and the posterior cerebral vein (p.c.v.). Along its length a vein is received from each gill-bar, which, like the hyoidean vein, extend from the anterior cardinal to the jugular. All these receive veins from the electric organ (e.v., Fig. 5). Cutaneous veins draining the gill pouches also enter the anterior cardinal. The post-orbital sinus is a narrow vessel running lateral to the auditory capsule, ventral to an overhanging ledge of cartilage, and connecting the anterior cardinal to the orbital sinus. The posterior cerebral vein passes through the cranium with the vagus and the vein on the right is larger than the one on the left. Each vein divides into two, the anterior branch on each side uniting with the one from the other side in front of the cerebellum, from which point a vein runs forward along each side of the brain and receives branches from its surface. The posterior branches of the cerebral veins join behind the cerebellum and pass back along the spinal cord as the myelonal vein.

A vein which drains the jaw muscles enters the post-orbital sinus. The orbital sinus receives laterally a vein which branches about the spiracle and another supplying the eye. The interorbital sinus (i.o.s.) which is very well formed, leaves the orbital sinus just posterior to the articulation of the rostral cartilages with the brain case. It runs for about half an inch on the antero-lateral inside wall of the brain case before passing ventrally through the cartilage to the under surface, where it unites with the interorbital sinus of the opposite side. Ventral to the brain case branches are received from the olfactory organ. This condition is very different from that described by O'Donaghue for *Scyllium canicula* in which "the interorbital vein is a small but well marked vein running from one orbit to the other in a canal in the basicranial cartilage, and it enters the orbit toward its posterior end just in front of and slightly below the large foramen in the cranium through which the sixth and main branches of the fifth and seventh nerves leave the cranium." In *Typhlonarke* it is much further forward, and for a part of its length runs on the inside of the cranium.

In the Stingray (Fig. 4, A) the anterior cardinal sinus receives anteriorly the post-orbital sinus, the posterior cerebral vein and from the gill-bars, the hyoidean and branchial veins as in *Typhlonarke*. Medianly four cutaneous veins (c.v.) enter the anterior cardinal sinus. Dorsally they unite into a longitudinal vessel which enters the ductus Cuvieri. The post-orbital sinus also receives a cutaneous vein quite close to the point at which a pre-spiracular vein also enters the sinus.

In *R. nasuta* the same general arrangement of veins entering the anterior cardinal sinus is found. At the anterior border of the orbit the anterior cerebral vein (a.c.v.) enters it medianly through a foramen in the wall of the brain case, having drained the fore brain. The orbital sinus also receives branches from the olfactory organ.

THE JUGULAR SINUS. (Figs. 4 and 5.)

In *Typhlonarke* the jugular sinus lies lateral to the ventral aorta and dorsal to the hypobranchial arteries, and it is connected to the anterior cardinal sinus by the hyoidean and branchial veins. In the middle line, ventral to the bifurcation of the ventral aorta, lies the thyroid sinus (t.s.) which is connected to the jugular sinus of each side by three veins. At its anterior end the jugular sinus drains a network of veins lying over the muscles of the mouth and jaws.

In *R. nasuta* the jugular sinus lies ventral to the afferent arteries but, posteriorly, the lateral hypobranchial artery is dorsal to it. It was not possible in either the Stingray or *R. nasuta* to trace the relations of the thyroid sinus, but the thyroid sinus depicted by Ferguson for *R. erinacea* is somewhat similar to that of *Typhlonarke.*

THE POSTERIOR CARDINAL SYSTEM. (Fig. 4.)

In *Typhlonarke* the posterior cardinal sinus (p.c.s.) empties into the lateral ends of the ductus Cuvieri by the cardinal veins (c.v.). Posteriorly it gives off the posterior prolongations of the cardinal veins, and medianly it also gives off a vessel, the haemorrhoidal vein (h.r.) supplying the rectal gland.

In the Stingray the posterior cardinals were not injected but they appeared to be paired as in the sharks, instead of fused into a large median sinus as in the rays.

In *R. nasuta* the posterior cardinal veins join to form the posterior cardinal sinus, as described by Parker. Two cardinal veins run posteriorly to the medial surfaces of the kidneys and then join. Parker gives a description of the connections of the veins of the posterior region and describes the haemorroidal vessel as joined to the lateral abdominal veins by large ileo-haemorroidal veins which passed on either side of the rectal gland. Rand and Ulrich did not find these in *R. erinacea,* but described a system of small anastomosing vessels connecting the haemorroidal and lateral abdominal veins. In the specimens of *R. nasuta* examined the arrangement agreed rather with Rand and Ulrich's description than with that of Parker for *R. nasuta* itself (Fig. 4, B). Ileo-haemorroidal veins similar to though smaller than those figured by Parker were found in a specimen of *R. naevus.*

THE SUBCLAVIAN VEIN. (Figs. 4 and 5.)

In *Typhlonarke* (Figs. 4 and 5) the pectoral girdle is much modified and the lateral portions are drawn out to form a canal in which certain vessels run, and this has various openings to allow the vessels to pass out and supply the fin. From the fin, the first brachial vein (1.br.) enters an anterior fontanelle (Fig. 5), passes inside the canal, crosses to the median side of the subclavian artery, and finally enters the ductus Cuvieri dorsally. The second brachial

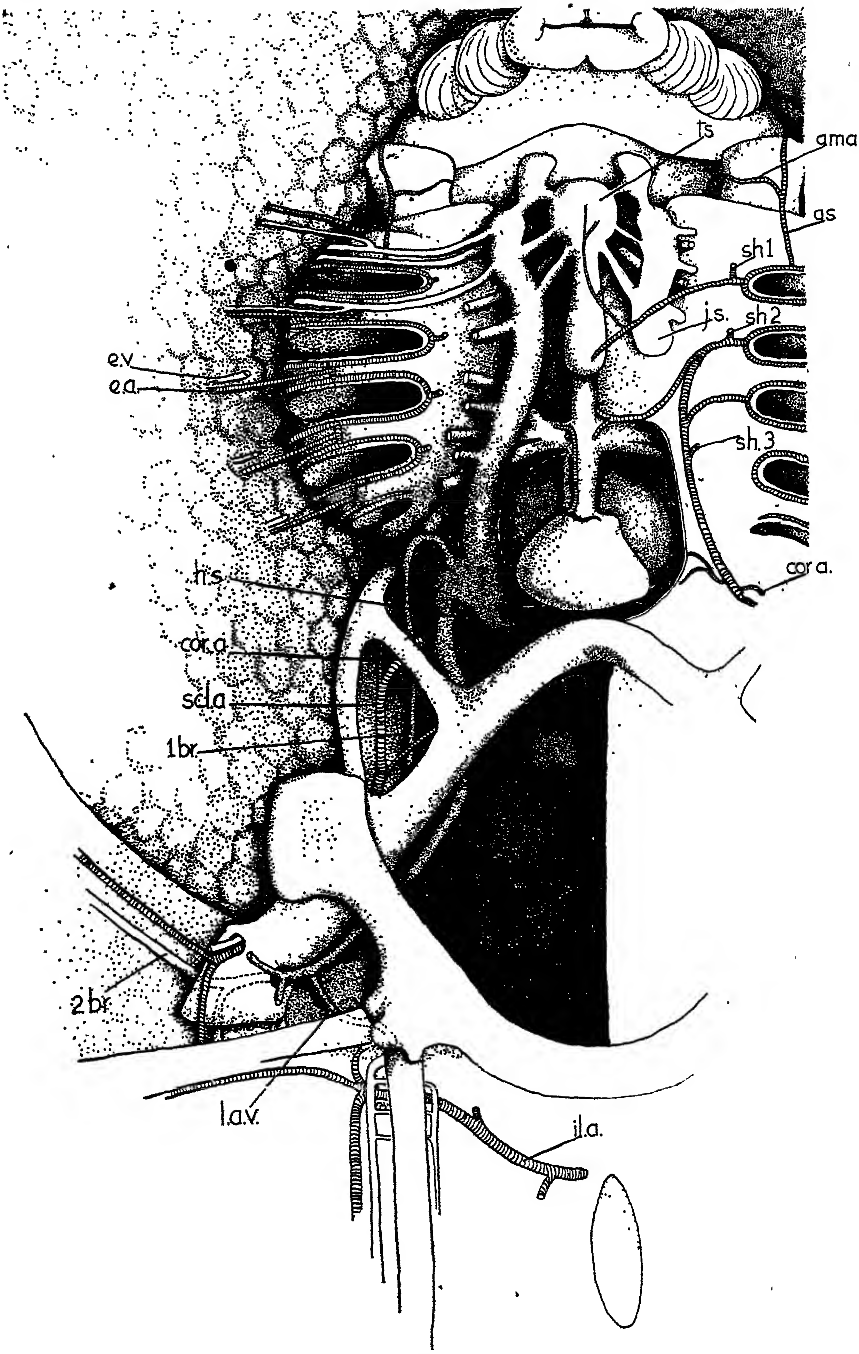


FIGURE 5.—A dissection of *Typhlonarke* from the ventral surface, showing the main arteries and veins. The ventral pharyngeal musculature, the pericardial wall and part of the abdominal muscles are removed and the dissection is deeper on the right side of the animal than on the left. (For explanation of letters see end of paper.)

vein (2.br.) enters the canal by a posterio-dorsal fontanelle, passes out by a medio-ventral opening and joins the lateral abdominal vein to form the subclavian vein.

In the Stingray (Fig. 4, A) the pectoral fin is supplied by three veins. The first (1.br.) drains directly into the ductus Cuvieri. This vessel passes between the propterygium and mesopterygium and divides into two, the propterygial branch running median to the artery. The second (2.br.) and third (3.br.) brachial veins join the lateral abdominal vein to form the subclavian vein, which enters the ductus Cuvieri laterally. The second vessel passes between the mesopterygium and metapterygium, and the third passes dorsal to the metapterygium.

In *R. nasuta* (Fig. 4, B) two veins enter the lateral abdominal vein, the anterior one (g.v.) running anterior to the propterygium and draining the gill pouches. The posterior one is the brachial vein which divides into a propterygial and a metapterygial branch to supply the fin. A transverse vessel joins the metapterygial branch to the lateral abdominal vein.

THE LATERAL ABDOMINAL VEIN.

The lateral abdominal vein in *Typhlonarke* is very short indeed, as the bases of the two paired fins are almost at the same level. It is a small stout vein running from the point where it joins the brachial vein towards the mid line, receiving the femoral vein and many small branches from the body wall. It does not join with its fellows of the opposite side. In the Stingray the two lateral abdominal veins are connected in front of the cloaca by the pelvic vein (p.v. Fig. 4, A). In this it resembles the sharks and differs from the rays in which the lateral abdominal veins arise from a number of small branches in the cloacal region. *R. nasuta* is typical of the rays. After giving off the femoral vein, the lateral abdominal vein forms a network upon the rectum and about the cloaca, some of the branches anastomosing with those of the haemorroidal vein as mentioned above.

THE FEMORAL AND CLOACAL VEINS.

In *R. nasuta* and the Stingray, the femoral vein and the cloacal vein join the lateral abdominal vein separately. In *Typhlonarke*, there is a large external basipterygial vein running lateral to the basipterygial cartilage and giving off branches between the fin radials, and several ones to the dorsal muscles. The internal basipterygial vein is short. It runs medial to the basipterygial cartilage and is joined to the external vein by commissural veins running ventral to the cartilage. In *R. nasuta* there is a superficial vein supplying the ventral surface of the fin, giving a branch parallel to the basipterygium and another along the front edge of the first radial. This joins the more dorsal of a pair of basipterygial veins which lie superimposed, one dorsal the other ventral to the fin radials and joined between each radial by commissural vessels. Into the ventral basipterygial vein, just before it enters the femoral vein, the pelvic transverse cutaneous vein is received. This vein leaves the lateral cutaneous trunk and passes round the back of the fin.

Cutaneous Veins.

The cutaneous venous system was studied only in *Raja*, the following description being of *R. batis,* but the other species appeared to be essentially similar. A lateral cutaneous vein of the usual type drains the trunk on each side, and each has parallel and dorsal to it an accessory lateral cutaneous vein. These two veins join immediately behind the scapular cartilage and pass deep to it as the subscapular vein to enter the ductus Cuvieri a short distance in front of the pectoral girdle. No dorsal or ventral cutaneous veins were observed. The extreme size of the fins and their extension forward alongside the head, result in a somewhat different arrangement of the veins in this region as compared with those of *Scyliorhinus* and *Squatina* (Marples, 1936, 1, p. 324 and 1936, 2, p. 836). In these species the dorsal pectoral cutaneous vein enters the subscapular sinus posteriorly to the scapular. In *Raja* a posterior dorsal pectoral cutaneous vein has this course, but in addition a large anterior dorsal pectoral cutaneous vein enters the subscapular sinus anteriorly to the scapular. It runs along the junction between the gill pouches and the propterygial cartilage on the dorsal side, and arises from branches on both the dorsal and ventral surfaces of the anterior region of the fin. It also receives branches from the head and from an extensive network over the gill pouches. The middle region of the fin is drained into two large veins, one of which enters the anterior dorsal pectoral cutaneous vein, opposite the second gill pouch, the other immediately in front of the scapular cartilage. The posterior end of the fin is drained by the posterior dorsal pectoral cutaneous vein. On the ventral side, branches from the anterior and middle regions of the fin collect into veins which pass dorsally between the fin and the gill pouches to enter the anterior dorsal pectoral cutaneous vein. The posterior ventral part of the fin is drained by the ventral pectoral cutaneous vein, which enters the lateral abdominal vein immediately behind the pectoral girdle. In the pelvic fin the pelvic transverse cutaneous vein connects the basipterygial veins to the lateral cutaneous vein as described in the previous section.

Discussion.

The general characters of the vascular system by which the rays are held to differ from the sharks are as follows:—The lateral dorsal aortae are interrupted; the first two epibranchial arteries do not enter the dorsal aorta separately; the three posterior afferent arteries leave the ventral aorta by a common stem; the lateral hypobranchial arteries are ventral to the afferent arteries; there are no median hypobranchial arteries; the anterior mesenteric artery supplies the dorsal side of the intestine only; there is no ventral intestinal artery; there is a single posterior cardinal sinus; the lateral abdominal veins are not united posteriorly by a pelvic vein but arise from small branches in the cloacal region.

This type of vascular system is found in *R. nasuta*, which is typical of the Rajiformes. The Torpedonidae are also very similar, with the addition of arteries and veins supplying the electric organ. *Typhlonarke* is one of the most highly specialised members of this family in that its eyes are rudimentary, the fins are reduced in size and the bases of the pectoral fins are very far back. It has no orbital

artery but otherwise its vascular system is essentially similar to that of *Torpedo* and *Raja*. It is interesting to find in the Stingray, however, certain shark-like features. The first two epibranchial arteries join the dorsal aorta separately, the three posterior afferent leave the ventral aorta separately, and there is a pelvic vein connecting the posterior ends of the lateral abdominal veins. Though it could not be determined for certain in the single specimen available it seemed that the posterior cardinal sinuses do not fuse into a large median sinus. It is impossible to generalise upon details of the vascular system of two species only, but it seems possible that an extensive study might produce evidence that the Centrobatoidei represent a different line in the Rajiformes as compared with the Rhinoraji and Torpedinoidei.

SUMMARY.

1. The vascular system of *Typhlonarke,* one of the Torpedonidae, is described and compared with that of *Raja nasuta* and the Stingray *Bathytoshia brevicaudata,* with notes on other *Raja* sp. and *Notastrape,* a normal member of the Torpedonidae.

2. *Typhlonarke* is blind and is highly specialised with regard to its fins.

3. The Stingray has several shark-like features in its vascular system but *Typhlonarke* and *Notastrape* are of the usual rajiform type.

4. The large ileo-haemorroidal veins described by Parker in *R. nasuta* were not found, but similar ones were observed in *R. naevus*.

REFERENCE LETTERS USED IN THE TEXT FIGURES.

a.c.s.—anterior cardinal sinus.
a.m.—anterior mesenteric artery.
a.m.a.—afferent mandibular artery.
a.s.a.—afferent spiracular artery.
b.f.—pelvic fin.
b.g.—pelvic girdle.
1 br. and 2 br.—brachial veins.
b.v.—branchial vein.
c.a.—coeliac artery.
cd.—posterior cardinal vein.
c.h.a.—commissural hypobranchial artery.
cl.—cloacal artery.
cl.v.—cloacal vein.
cn.a.—coronary artery.
cor.a.—coracoid artery.
c.v.—cardinal vein opening into ductus Cuvieri.
c'.v'.—cutaneous vein.
d.bt.—dorsal basipterygial vein.
d.C.—ductus Cuvieri.
d.c.—dorsal coronary artery.
d.m., d'.m'.—arteries to dorsal musculature.
d.p.—dorsal pericardial artery.
e.a.—branchial electric organ artery.
e'.a'.—hyoidean electric organ artery.
ef.a.—epibranchial artery.
e.s.a.—efferent spiracular artery.
e.v.—electric organ vein.
ex.b.—exterior basipterygial vein.
f.v.—femoral vein.
g.p.—gill pouches.
g.v.—vein draining gill pouches.
h.—hyoidean epibranchial artery.
hr.—haemorroidal veins.
h.v.—hepatic sinus.
i.a.—innominate artery.
i.b.—internal basipterygial vein.
i.c.—internal carotid artery.
il.a.—iliac artery.
i.o.s.—inter-orbital sinus.
j.s.—jugular sinus.
l.a.a.—lateral abdominal artery.
l.a.v.—lateral abdominal vein.
l.c.—lateral cutaneous vein.
l.h.—lateral hypobranchial artery.
n.c.—neurocranium.
o.a.—orbital artery.
o.s.—orbital sinus.
ov.a.—ovarian artery.
p.c.—posterior cerebral vein.
p.c.s.—posterior cardinal sinus.
p.cor.—posterior coronary artery.
p.f.—pectoral fin.
p.g.—pectoral girdle.
p.m.—posterior mesenteric artery.
p.o.s.—post orbital sinus.
p.t.c.v.—pelvic transverse cutaneous vein.
p.v.—pelvic vein.
s.a.—superficial artery.
s'.a'.—superficial artery of hyoid arch.
scl.—subclavian artery.
s.h. 1–3.—superficial hypobranchial arteries.
s.v.—superficial vein.
t.s.—thyroid sinus.
v.a.—ventral aorta.
v.a.a.—ventral abdominal artery.

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Pollicipes spinosus Quoy and Gaimard, I: Notes on Biology and Anatomy of Adult Barnacle.

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INTRODUCTION.

Amongst modern cirripedes, the genus *Pollicipes* has frequently been regarded as lying closest to the original stock. Such views have been based rather on the arrangement of valves of the mantle than on the animal itself—its biology and anatomy. Hence it is more from this latter view-point that the New Zealand section of the genus *Pollicipes* is here examined.

Taxonomy: By priority, the genus in question should be termed *Mitella*, the name *Pollicipes* pre-dating the introduction of binomial nomenclature. But following Darwin's strong arguments for making an exception in this case (Darwin, 1851, p. 293), the term *Pollicipes* has been extensively used in geological and zoological work. Hence its employment here.

Three species —*P. spinosus* (Q. and G.), 1834, *P. sertus* Darwin 1851, and *P. darwini* Hutt, 1879— have been described for New Zealand. But field-work involving the handling of large numbers of specimens has led the present author to concur with the opinion of Jennings (1914, p. 293), namely, "To conclude, I am practically certain that the New Zealand species of *Pollicipes* so far recorded come under one species only, which, by priority, should be called *Pollicipes spinosus* Quoy and Gaimard."

Subsequent to Jennings' work, Broch (1921, pp. 247-251) has described a New Zealand species, *Protomitella paradoxa,* in which the large form (female or hermaphrodite?—penis is described as "very short," and internal anatomy is not considered) is close to some specimens of *P. spinosus.* However, he further describes two small individuals, on the "inner edge of the scuta at the apex of the rostrum" of one Plimmerton specimen, as dwarf-males. Their internal anatomy (presence or absence of testes or ovaries) is not considered. Externally they are not unlike young *P. spinosus* specimens. Fuller data would be of much interest. The present author feels hesitant to regard *Protomitella paradoxa* as distinct from *Pollicipes spinosus* until more positive evidence is available. Her own field-work at Plimmerton (one of Broch's type localities) showed a great abundance of *P. spinosus,* scattered specimens of *Calantica villosa,* and no other littoral scalpelliform cirripedes. The examination, both macroscopically and under dissecting binoculars, of large numbers of *P. spinosus* and *C. villosa,* both from there and other New Zealand localities, at various seasons, has shown no small specimens which might be dwarf males. Incidentally, this apparent total absence of complemental males in more than 100 New Zealand specimens of *C. villosa* perhaps marks it as a distinct form from the extra-New Zealand species.

Material and Methods: Abundant fresh material was available. Live specimens were kept temporarily for observation in a glass tank with a tap-driven aerating pump. Young were reared in vitro continuously from the one-cell egg to the cypris stage. An account of their development is postponed to a subsequent paper, but the times for embryonic and nauplius phases are considered here.

The anatomical portion is based partly on dissections, partly on serial sections. Both alcohol-preserved and fresh specimens were dissected under a dissecting binocular. For sections, alcoholic Bouin's and mercuric chloride were the chief fixatives used. Usually the "body" was removed from the mantle at the time of fixing, but some specimens were decalcified by changes of 1% hydrochloric acid in 70% alcohol and sectioned entire.

Paraffin-infiltration of the body was slow, 5 to 10 days in the paraffin oven giving best results. Sections were cut at from 2.5 to 50 microns. Mallory's triple stain was chiefly used. Drawings of sections and appendages were made with the aid of a camera lucida.

Acknowledgments: The present paper represents, with modifications and condensation, a thesis presented for Diploma of Honours in Zoology in the University of New Zealand. The greater part was carried out in the University of Otago, and the writer wishes to thank Professor Marples for suggesting *Pollicipes,* and for helpful advice about lines of attack.

Biology of *P. spinosus.*

Distribution and Habitat: This species, reputedly endemic to New Zealand, has been recorded from numerous localities from North Auckland to Stewart Island. The present writer has found it occurring around Dunedin in abundance at Bruce's Rocks and Brighton, fairly abundantly at St. Clair, Long Beach, Karitane, and other coastal-rock localities; around Wellington extremely abundantly at Island Bay and Plimmerton, present near Paekakariki and elsewhere; and at Stewart Island in moderate abundance south-east of Halfmoon Bay.

It appears confined to coastal rock localities where water surges violently. It is absent in bays and on rock points in harbours and inlets. Likewise it is absent from rock-pools, from low smooth rocks, or where an outer reef protects inner rocks from larger waves. But if great masses of inter-tidal rocks are separated by narrow channels through which water surges wildly, especially if the rock surfaces are overhung, colonies of *P. spinosus* are almost invariably found.

The chief concentration of individuals is at about half-tide level. Some occur nearly down to low tide, overlapping with the vertical distribution of *Calantica villosa.* Occasional specimens are probably above actual high-tide level. But their position is such that waves running up rock-channels would reach them long before high tide on all but the calmest days.

Specimens may occur singly, in small groups, or in colonies (Fig. 16), sometimes up to a foot or more in diameter, running into hundreds of individuals. In most cases they are attached directly to the rock. Sometimes, however, one has settled on an-

other *Pollicipes* specimen, or on a mussel or other animal itself attached to the rock. The site of attachment of small specimens suggests that the cypris always fixes itself in a cranny and not on a flat or protruding surface of rock.

The external form appears closely related to the dwelling place. Isolated individuals on comparatively exposed rocks show numerous well-developed latera, and irregular main valves largely uncovered by integument and often spotted with black (Fig. 15). Such forms, if the terga are long, are probably Hutton's *P. darwini*, but if the tips are worn or broken they would be *P. spinosus* in its limited sense. Where many occur close together in an exposed colony, central specimens show fewer and smaller latera, probably due to friction between adjacent barnacles (Fig. 13). In more sheltered colonies the latera are even less conspicuous, being almost covered by black integument; while in extreme forms from darkest crevices even the main valves may be concealed (Fig. 14). If they are not completely covered, these valves, sheltered from wearing agencies, are smooth and regular, with unbroken tips and a well-developed rostrum (*P. sertus* of Darwin).

The length of the peduncle is also variable, ranging from about half that of the capitulum in some exposed individuals to three times its length or more in specimens in the centre of colonies or other positions where the mantle opening would otherwise be below the level of its surroundings.

Altogether, whereas considerable diversity of external form occurs, the examination of a few hundred specimens in the field indicates that this is merely epharmonic, closely related to the precise dwelling place of the individual, and with all intermediate stages connecting its several extremes.

Feeding: Neither specimens in a tank nor those in the field show the almost rhythmical extrusion and withdrawal of cirri that characterises many barnacles. Instead, the cirri remain in the extruded position for considerable lengths of time. In the tank, nothing happens unless the cirri are touched. But, if one watches a colony in its natural surroundings while the tide is coming in, about half an hour after waves begin to wash the colony first one individual and then another will slowly extrude its cirri. These are then kept continuously expanded, forming a semi-circular net through which the water rushes. Between one wave and the next the cirri may show twitching, incurling actions, by which presumably food particles are passed forwards to the trophi. But unless an animal is considerably molested, the cirri are not withdrawn into the mantle.

Conceivably it is the loss of the habit of repeatedly extruding and withdrawing the cirri that controls the type of habitat in which *P. spinosus* can survive; for the collecting of food appears to depend not so much on the activity of the animal as on the movements of the surrounding water.

Food: Judging by gut contents, smaller crustacea constitute the bulk of the diet. Most samples examined had the remains of one or more Isopod or other Malacostracous crustacean, often of no mean size. During the breeding season nauplius limbs, apparently of

its own species, were not infrequent. Pieces of algae are usually present. Other recognisable remains have included polychaet setae, diatoms, nematodes, and two species of mite.

Seasonal Variations of Gonads: In June and July, the ovaries are inconspicuous in the peduncle, in most cases showing microscopically only minute, dull orange ova. Samples of barnacles examined during spring show considerable variation, ova being minute in the ovaries of some individuals, fairly large in those of others. But by November or December the upper regions of most peduncles are filled with masses of large bright orange ova, soon to become the embryos of the oncoming season. At the beginning of March, the only individuals in which ova are not readily seen in the peduncle are some which have young bright orange ovarian lamellae in their mantle cavities. At this time, specimens without ovarian lamellae mostly show peduncles filled with large eggs, while those with pale ovarian lamellae (i.e., embryos about to hatch) show moderately well developed eggs in the ovaries.

Likewise, the seminal vesicles, usually conspicuously distended with a milky mass of sperms in the early months of the year, are in the majority of specimens slender and inconspicuous from June to October. In both these months, however, some individuals have been found with moderately-extended seminal vesicles, whose contents viewed microscopically consist of a swirling mass of active, filiform sperms.

Hence it appears that eggs and sperms are slowly being formed for several months before fertilisation occurs.

One specimen of *P. spinosus* and one of *C. villosa* have been found with ova in the oviducts. These were distributed fairly evenly along them, from the peduncle to the oviduct opening, placed a millimeter or two apart. Their bright orange colour rendered the course of the ducts readily apparent.

Ovarian Lamellae: The ova are presumably fertilised as they emerge from the oviduct openings and become cemented together to form the flat paired ovarian lamellae in the mantle cavity. Earlier workers (Darwin, 1851, p. 61, and Gruvel, 1905) have presented good evidence for the occurrence of both self- and cross-fertilisation in barnacles. In the present species, whereas isolated adults presumably fertilise their own eggs, in the dense colonies commonly seen cross-fertilisation could readily occur.

Each ovarian lamella is an irregularly oval sheet of embryos which are bound together by a transparent matrix. Direct counts made of the number of embryos per lamella (by teasing them apart and counting in a squared petrie dish) gave 806 in a fairly small lamella, 1416 in one of slightly less than average size, and 3574 in a fairly large lamella (27 x 16 mms.). Hence the number of embryos per pair of lamellae may be regarded as ranging from about 1500 to over 7000.

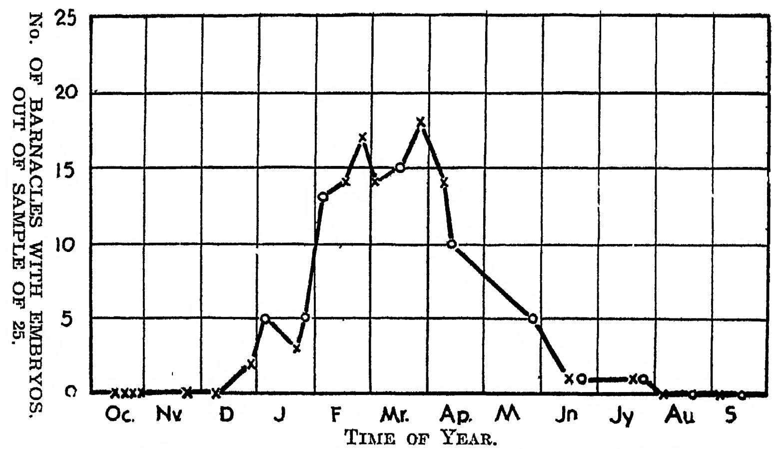
Two pairs of lamellae collected in mid-February, whose embryos were at the one-cell and two-cell stage, showed continuous in vitro development; natural hatching of nauplii occurring 30 and 31 days later.

Reproductive Season and Larval Periods: To get a picture of the reproductive season, samples, each of 25 large barnacles, were col-

lected at different times of year and opened. After a preliminary examination at Dunedin during 1940, samples were taken approximately monthly (partly at Dunedin, partly at Wellington) during 1941, and less regularly subsequently. Of the 26 samples shown in graph I, circles represent 1941 samples, crosses later ones. From this it is seen that the breeding season commences in late December or early January, is at its maximum during February, March, and early April, and gradually falls to zero by August. While detailed data are not at hand for drawing comparisons, what figures are available indicate that this breeding peak follows close behind the peak of the maximum annual temperature of the sea water.

Nauplius larvae hatched from lamellae have on several occasions been reared to the cypris stage. Times taken for the nauplius phase were 13–14 days during the warmest conditions, 2½ weeks for the next, and 20–21 days when the temperature was lowest.

No cypris larvae reared from nauplii became attached and metamorphosed to the adult form. Hence the duration of the cypris phase is not known. A single attached cypris with chitinous prevalves was collected amongst *P. spinosus* adults on 26/5/40. (Direct proof is lacking, but it is almost certainly of the same species.) It was 0·9 mm. long, as compared with the length of ·84–·88 mms. of free cypres reared in vitro. The slightness of this increase, together with the date of collecting the specimen, suggest that the cypris phase is not long—probably shorter rather than longer than that for the nauplius. So it would seem probable that most of the young settle between mid-March and mid-June.



GRAPH 1.—SEASONAL OCCURRENCE OF EMBRYOS.

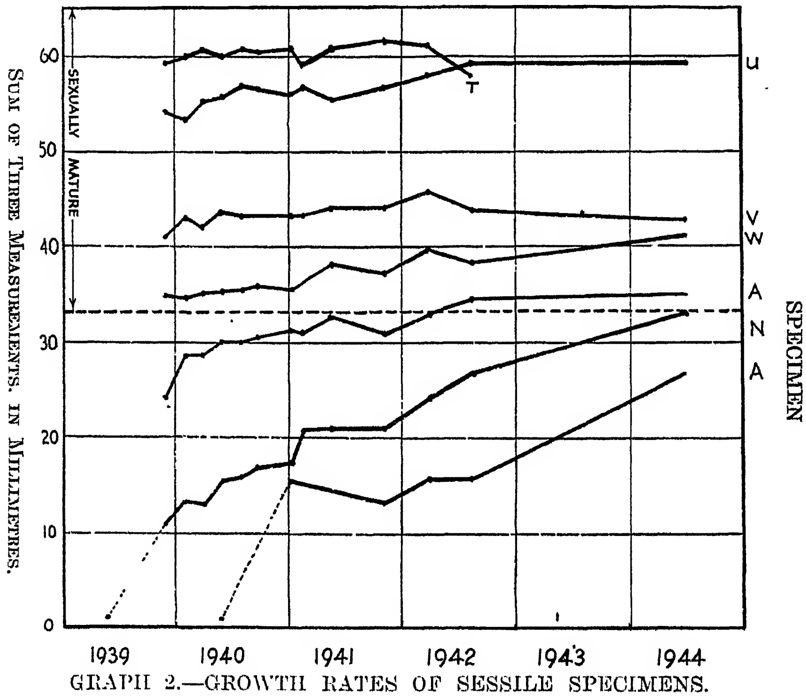
As during the two and a-half months' peak of the breeding season only about three-fifths of the individuals have embryos, and as one batch of embryos has been found to take one month to develop, it would appear that an average of three-fifths of a month elapses between the hatching of one lot of nauplii and the fertilising of the next series of eggs. From this data and the length of the main breeding season (Graph I), it would seem that on an average one sexually-mature adult produces two batches of larvae per season.

TABLE I.—Growth Rate.

Specimen	Measurement / Date	5/12/39	30/1/40	27/3/40	24/5/40	21/7/40	19/9/40	2/1/41	9/2/41	14/5/41	27/10/41	28/3/42	16/8/42	25/6/44
A	1	7.5	9.5	9.5	10	10.5	10.5	10.5	10	10.5	10	10	11.5	12
	2	10.5	13	13	14	13.5	13.5	14	14	14.5	14	15.5	15	15
	3	6	6	6	6	6	6.5	7	7	7.5	7	7.5	8	8
A'	1							5			5	6	6	9.5
	2							8			6	7	7	11.5
	3							2.5			2	3	3	6
D	1	9	10	10.5	10.5	10.5	10.5	10.5	11	11	11	12	12.5	15
	2			11	11	11	11	11	12	12	12	13	13	14
	3	4	6	5	6	5.5	6	6	6.5	7.5	7	9	8	9
E	1	10	10	10.5	11	12	11	11.5	12.5	13	13	12	12	12
	2				10	10.5	11	12	12	13	12.5	13	14	12.5
	3	5	5.5	5.5	6	7	7	8	7	7.5	7	8	8	7
N	1	3.5	5	4	5.5	6	6.5	6.5	7	7	7	9	11	13
	2	5	5	5.5	7	7	7.5	8	9	9	9.5	10	9	12
	3	2.5	3	3	3	3	3	3	5	5.5	5	5	7	8
T	1	21	21	23	23	23	23	23	22.5	23.5	24	23.5	21	
	2	24	24	22	22	23	22	23	22.5	22.5	22	22	23	
	3	14	15	16	15	15	15.5	15	13.5	15	16	16	14	
U	1	20	19	19.5	20	21	21	20	20	19.5	21	21	21	22
	2	22	22	23.5	24	24	24	24	25	24	24	25	25	24
	3	12	12	12	12	12	12	12	12	12	12	12	13	13
V	1	17	18	17	17.5	17.5	17.5	17.5	16.5	17	18	18	18	18.5
	2	14	15	16	16	15.5	15.5	15.5	15.5	15	15	16	15	14
	3	10	10	9	10	10	10	10	11	12	11	12	11	10
W	1	13	13	13.5	13.5	13.5	14.5	14	14	14	14	15	15	16
	2	13	13	13	13.5	13.5	13	13.5	13.5	14	14	14.5	14	13.5
	3	9	8.5	8.5	8.5	8.5	8.5	8	9	10	9	10	9	11.5

Growth Rate: The growth rate was studied by measuring several specimens in marked positions in a channel at Bruce's Rocks over a period of 4½ years. Originally, 23 specimens, ranging from the smallest accessible barnacle seen in the channel to full-sized individuals, were selected for measuring. Within three months, five young specimens (forming a small colony in a position unusually exposed for the species) died and subsequently disappeared. Soon afterwards, six others, whose environment was probably upset by

the removal of a sheltering rock, also died. Of the remaining 12, the largest (T in Table I, and Fig. 15) was limp and flabby on the second-last date of measuring, had vanished by the last; and two were not certainly identifiable during the later, less frequent visits; but nine provided a continuous series of measurements. In addition, one tiny specimen (A^1) was first seen in January, '41, between two of the barnacles that were being measured, and hence was subsequently recorded. Its apparently high first figure (Graph II, A^1) was probably due to inaccurate measuring owing to its awkward position. An error of $\pm$ 1 mm. is also liable to have occurred in other measurements, as not infrequently the portion being measured was not readily accessible to the tips of the dividers.



GRAPH 2.—GROWTH RATES OF SESSILE SPECIMENS.

As total width or length of a specimen could vary with its state of contraction at the time, and as calcareous valves were liable to erode, hence not showing regular increments, it was deemed advisable to compromise by making three measurements of each specimen on each date. These were: (1) Tip tergum to tip rostrum; (2) width, base carina to base rostrum; (3) length of exposed portion of tergum, each in millimetres (Fig. 7). This data for nine specimens on 12 dates is given in Table I. For simplification, the three measurements are added and the results show graphically for seven of these (Graph II). The two smallest specimens, A^1 and N, had presumably each settled during the autumn prior to their initial measurements, when the equivalent sum of dimensions of the newly-attached cypris would be about $1\frac{1}{4}$ mms (dotted line, Graph II).

The measuring and opening of a number of specimens during the breeding season indicated that reproduction typically commenced when the sum of the above three measurements exceeded 33 mms. Hence, from Graph II it appears that about 5 years elapse between the settling of the cypris and the attaining of sexual maturity. These specimens, however, are little more than half grown. The graph indicates that at least as long again is required for "full size" to be attained while anyway as many years again may elapse before death ensues; i.e., while recognising the limitations of this data, it may probably be assumed that one individual of *P. spinosus* is producing young for a period of at least 10 years.

How Many Larvae Does One P. spinosus Adult Produce? The data provided give a basis for a rough average estimate. Taking 10 years as the length of the reproductive period (the weakest assumption, as it may be much longer), two pairs of lamellae as the annual average, and 3000 larvae as the average per pair of lamellae, then one *P. spinosus* barnacle would produce during its lifetime some 60,000 larvae.

Anatomy of *P. spinosus*.

Externals: The external appearance of the peduncle and capitulum is shown in Figs. 7, 13, 14, 15, and their variations have earlier been discussed. The exposed portions of the valves and spines are pale grey, sometimes with a lavender tinge. The integument is black around the valves, but pales to yellow-brown towards the base of the peduncle of more sheltered specimens. It becomes dull red on alcoholic preservation. As the capitular valves have already been described in detail by Darwin (1851, pp. 324–9) and others, they will not be further considered here.

The actual "body" of the barnacle lies inverted in the mantle-cavity, being attached anteriorly in the region of the scuta and the rostrum. It is regarded as consisting of the last three head segments and six thoracic segments of the cypris (the first, the antennulary and probably the antennary larval segments being incorporated in the peduncle). As in cirripedes generally, this "body" has rotated back dorsally at metamorphosis until its anterior end is directed towards the ventral surface of the cypris, its posterior end towards the larval dorsal surface. Hence its cirri (whose bases overlie the ventral nerve-cord) protrude through the mouth-opening which is across the posterior end of the cypris (Fig. 5).

The mouth lies in the posterior half of the body, its position being further back than in most cirripedes. This is presumably correlated with the position of the scuta and their adductor muscle, which are placed more posteriorly over the body than in the majority of pedunculates. The gut is consequently bent in a very deep U.

The swollen anterior part of the body, enclosing the bend of this U and placed beneath the adductor muscle, is termed the prosoma (Fig. 8, pr.). Between the prosoma and the mouthparts there can be seen by transparency two semi-translucent zones—the excretory organs (Fig. 8, 1 ex. and ev.). The anus, a longitudinal slit, lies just dorsal to the base of the penis, between this and the caudal appendages. The long, tapering penis is deep purple, very finely

annulated, and sharply reflexed forwards between the cirri, so that its tip, bearing the male opening, usually lies close to the mouthpart projection (Fig. 10). The integument all over the body is well chitinised, staining blue with Mallory's. Over the prosoma it is smooth except for a few irregularly-placed hemispherical papillae. But over the thorax it is embossed to form oval swellings (Fig. 8). These, like narrower pads above them on coxopodites 1–5, are filled with loose connective tissue. The thin integument of the body (8 to 30 microns thick) is continuous with that lining the mantle and covering the capitulum and peduncle (except where interrupted by valves or scales). From the mantle-lining laterally, in the region of the prosoma, protrude two small papillae, the ovarian frenae. The heads of these carry numerous minute short bristles, by which they attach the ovarian lamellae to the mantle.

The Segmental Appendages: The minute antennules, embedded in the base of the peduncle, can still be seen in young sessile specimens if these are carefully removed from their substratum and boiled in caustic potash. In favourable instances (Fig. 1) there can be distinguished the long arm, the sucker, and the tiny lateral segment of the cypris antennule, while the remnants of stouter setae may also be apparent. As in other cirripedes, no vestige of the larval antennae was found.

The paired *mouthparts* lie under the broad, bullate labrum. The *mandibles* show three large teeth (Fig. 4, A, B, C). Commonly two (but sometimes three or one) smaller teeth occur between A and B, while occasionally a small one is also present between B and C. The mandibular palps are fringed terminally with numerous setae whose length varies among different individuals (Fig. 2, mn.p.). The *maxillules* and *maxillae* are shown in Figs. 6 and 2. On the posterior bases of the latter lie the openings of the excretory organs on slight projections (unlike the condition in *C. villosa,* where they project strongly).

The *cirri* each have a long coxopodite, a short, stout basipodite, and two multi-articulate rami (Fig. 3). None of the rami are markedly reduced, as in many cirripedes, and the first pair of limbs is placed close to the second (Fig. 8). The number of segments per ramus for any limb varies among different individuals and even between two sides of one specimen. Average numbers (giving legs and rami from before backwards) are: 11, 11; 13, 14; 15, 16; 16, 16; 16, 17; 17, 17.

Peduncle: The upper portion, immediately beneath the capitulum, is usually largely occupied by the ovaries. The attachment end contains the cement glands, which have not been studied in detail.

Transverse sections (Fig. 24) show an ectoderm layer of tall, clear cells, outside which lies a thick layer of faintly laminated chitin. Spaces in this in decalcified sections represent the positions of the scales. Externally bounding the chitin is a narrow, fuchsin-staining cuticular sheath. Inside the ectoderm lie three layers of muscles—diagonal, circular, and innermost a broad zone of longitudinal muscles which pass from the mantle to the base of the peduncle. Scattered through the loose connective tissue of the

peduncle is a system of stout unstriated anastomosing fibres, staining a vivid red with fuchsin and more or less radially arranged (Fig. 31). From them more slender fibres pass out through the muscle layers, terminating among the ectoderm cells in fine branches attached to the integument.

Somatic Muscles (Fig. 17) : Despite the comparatively immobile life of the adult, a fairly complex muscular system is developed. Muscles may show broad zones of attachment to the body-wall surface; circumscribed origin or insertion from deep intuckings of the body-wall (termed apodemes, the chief of which occur between the mouthparts and the prosoma, at the sides of the prosoma in the U-bend of the mid-gut, and between the bases of the cirri) ; or finally may take origin from endosternites. There are three main endosternites, all median—two in the U-bend of the gut (Fig. 10 v.en. and d.en) and a slender four-horned one in the mouthpart projection posterior to the oesophagus (Fig. 11, end.). These take up aniline blue stain, but do not withstand boiling in caustic potash.

The main elements of the muscular system can be briefly functionally analysed in relation to the movements shown. *Bending and contracting of peduncle:* Its longitudinal, circular, and diagonal muscles have already been described. *Control of mantle opening:* The short cylindrical adductor muscle, attached to the centre of each scutum, is by far the stoutest in the body. It consists of fibres whose faint striations are not nearly as clear as those of many other of the somatic muscle fibres. *Raising of body in mantle:* Several pairs of stout muscles, originating at the occludent margins of the scuta and beneath the rostrum, radiate out slightly to broad insertions on the sides of the prosoma (Fig. 17, m.b.m.). *Bending of body:* Long lateral body-wall muscles, attached posteriorly to successive thoracic intuckings between limb-bases, have broad insertions anteriorly on the sides of the prosoma (Fig. 17, l.b.m.). *Movements of cirri:* Of muscles passing to the legs, some are attached basally to apodemes on the same side of the body (Fig. 17, c.m.), others cross over to the opposite side between the central body-wall and the nerve-cord (Fig. 27). *Movements of mouthparts:* The numerous short stout trophic muscles chiefly take origin from the intuckings of the integument at the base of the mouthpart projection. *Lateral contraction:* Muscles attached medianly to the upper (ventral) endosternite radiate out to intuckings of the body-wall above and below the excretory organs (Figs. 12, rad., 17, r.m.). Below the lower endosternite, two transverse muscles separate the excretory organs from the testis (Fig. 12).

Gut (Fig. 10) : Fore-, mid, and hind-gut regions are sharply differentiated. The long narrow fore-gut or oesophagus shows in section a narrow star-shaped lumen (Fig. 23), separated from the thick muscular wall by the tall ectoderm cells and layer of chitin that these secrete (Fig. 32). As well as longitudinal and circular muscles, extrinsic fibres are present which run out anteriorly to the apodeme between trophi and adductor muscle, posteriorly to the ventral endosternite (Fig. 10). At the junction with the mesenteron, the diameter of the lumen suddenly increases greatly, and the chitinous lining of the oesphagus ends as a splayed-out, expanded

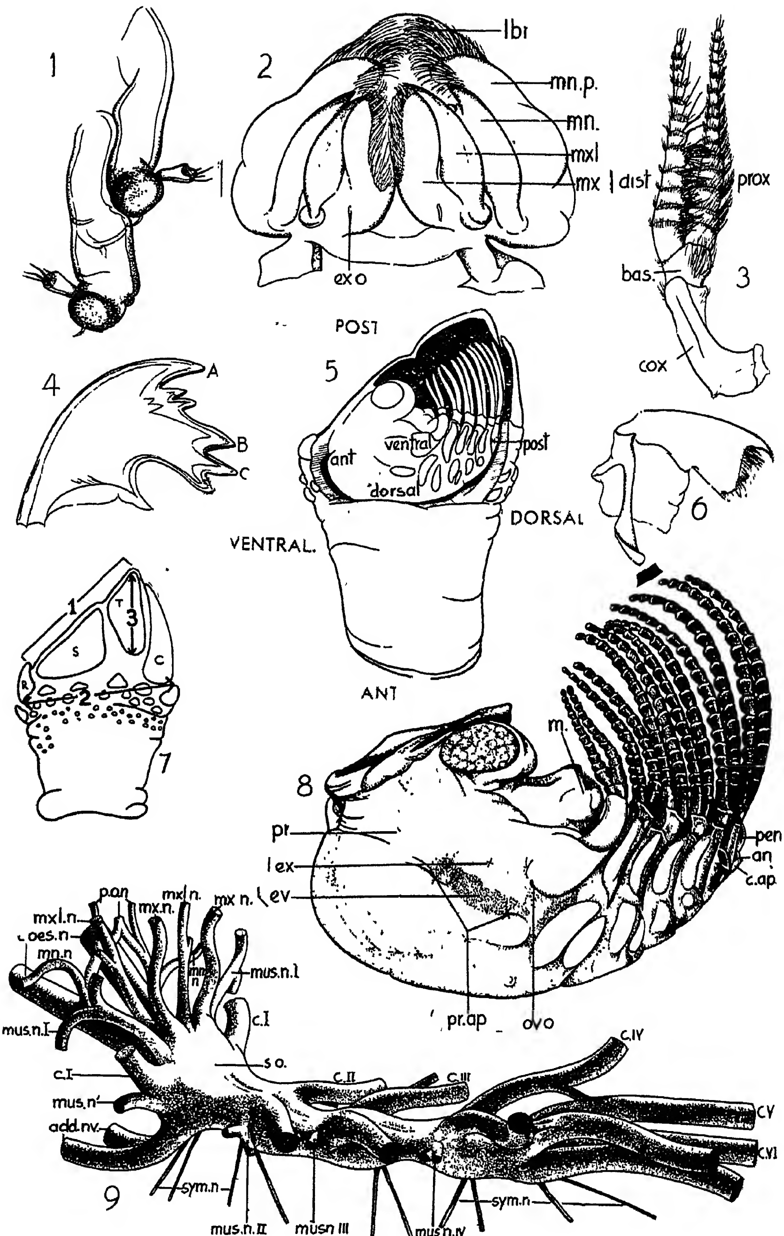


FIG. 1.—Antennules from base of peduncle of young sessile specimen, × 210.
FIG. 2.—Mouthparts in situ, viewed from behind, × 14. lbr., labrum; mn.p., mandibular palp; mn., mandible; mxl., maxillule; mx., maxilla; ex.o., excretory opening.
FIG. 3.—First right cirrus, from behind, × 7. dist., prox., distal, proximal; bas., basipodite; cox., coxopodite.
FIG. 4.—Mandible, × 14.
FIG. 5.—Adult with half of mantle removed, for comparison of orientation of cypris (capital letters) with 'body' of sessile form (small letters). Natural size.
FIG. 6.—Maxillule, × 14.
FIG. 7.—Adult, natural size, showing measurements taken in growth-rate study. R, rostrum; S, scutum; T, tergum; C, carina.
FIG. 8.—'Body,' × 4. pr., prosoma; l.ex., lateral excretory sac; ev., evacuatory sac; pr.ap., prosomal apodemes; ov.o., oviduct opening; m., mouth; pen., penis; an., anus; c.ap., caudal appendages.
FIG. 9.—Postero-lateral view of nerve cord (ventral surface uppermost); drawn from model based on dissections and serial sections. (See text for lettering.)

FIG. 10.

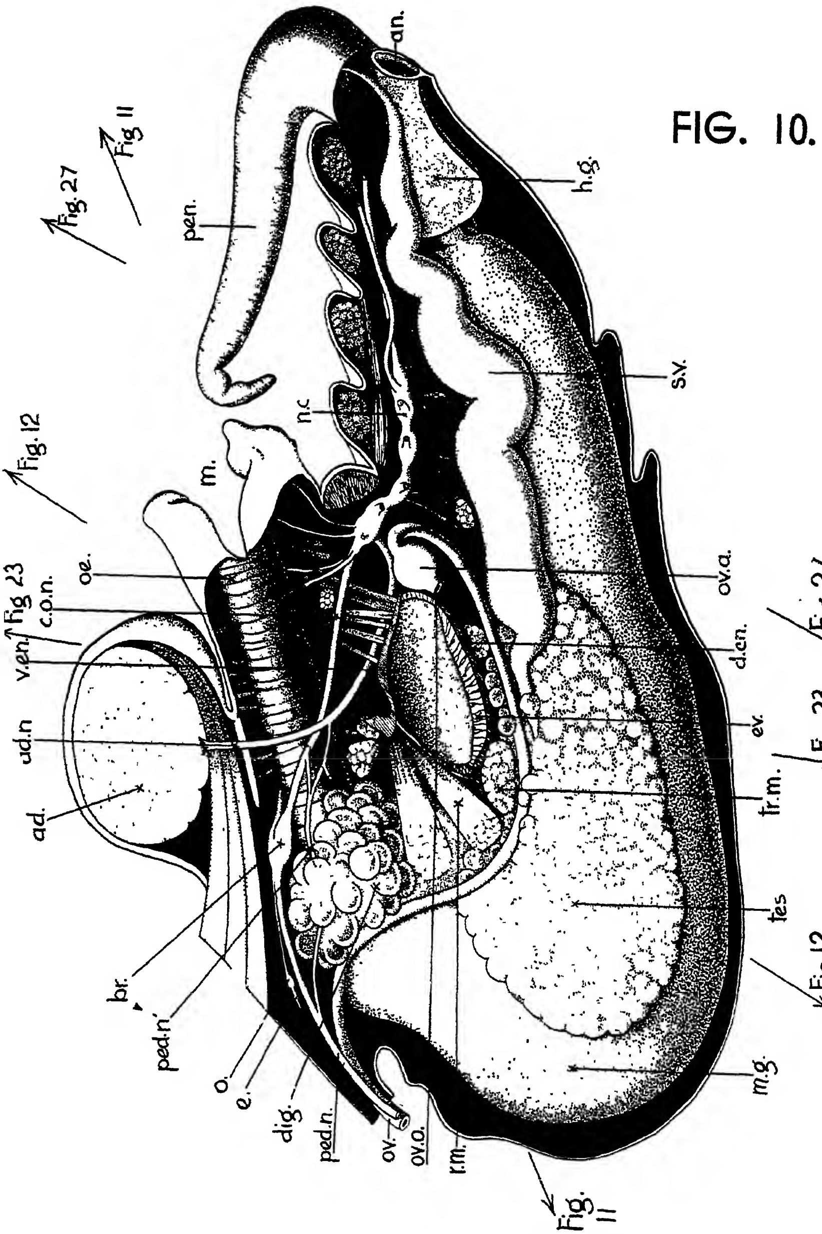


Fig 10.—Lateral reconstruction of internal anatomy of body; based on a medium longitudinal section, series of transverse sections and dissections. ad., adductor muscle; ad.n., adductor muscle nerve; an., anus; br., brain; c.o.n., circum-oesophageal nerve; d.en., dorsal endosternite; dig., digestive gland; e., eye; ev., evacuatory sac; h.g., hind-gut; m., mouth; m.g., mid-gut; n.c., nerve cord; o., ophthalmic ganglion; oe., oesophagus; ov., oviduct; ov.a., oviduct atrium; ov.o., oviduct opening; ped.n., peduncular nerve; ped.n'., branch to last; pen., penis; r.m., radial muscles; s.v., seminal vesicle; tes., testis; tr.m., transverse muscle; v.en., ventral endosternite.

Fig. 11

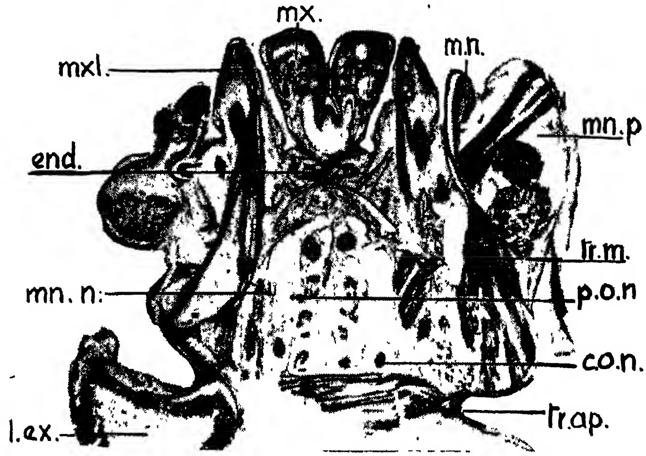


Fig. 12

Fig. 13

Fig. 14

Fig 15

Fig. 16

FIG. 11.—T.S. Mouthparts, × 18. (For angle of section, see. Fig. 10.) c.o.n., circum-oesophageal nerve; end., endosternite; l.ex., lateral excretory sac; mn., mandible; mn.n., nerve to mandible; mn.p., mandibular palp; mx., maxillule; p.o.n., post-oesophageal nerve; tr.ap., trophic apodeme; tr.m., trophic muscles.

FIG. 12.—T.S. Body. × 9. (For angle of section, see. Figs. 10 and 17.) c.o.n., circum-oesophageal nerve; ex.m., extrinsic muscles of oesophagus; l.ex., lateral excretory organ; ov., oviduct; rad., muscle radiating from v. endosternite to body-wall.

FIGS. 13, 14, 15.—Specimens of *P. spinosus*, natural size. Fig. 13, from centre of colony; Fig. 14, sheltered form; Fig. 15, solitary exposed individual (specimen T in growth-rate study).

FIG. 16.—*P. spinosus* colony, 2/5 natural size.

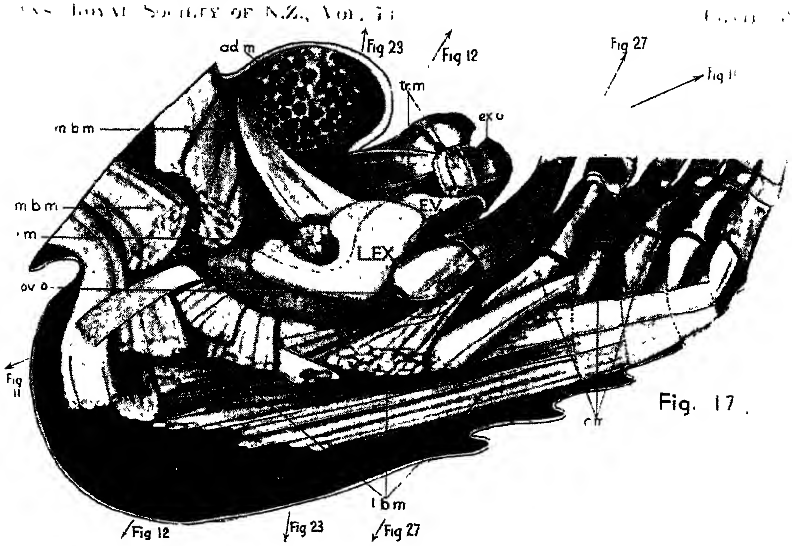


Fig. 17

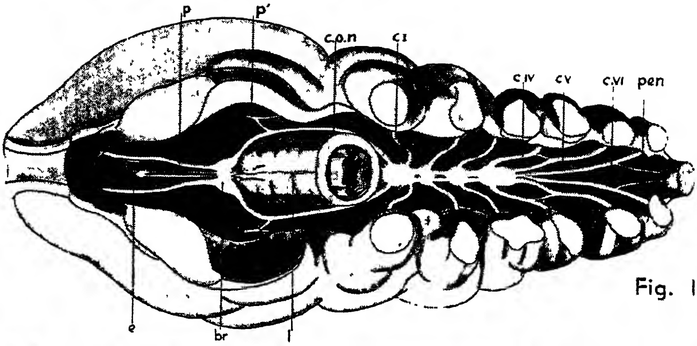


Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 22

FIG. 17.—Superficial dissection of body, showing muscular and excretory systems. ad.m., adductor muscle; c.m., muscles to cirri; ev., evacuatory sac; ex.o., excretory opening; l.b.m., lateral body-wall muscles; l.ex., lateral excretory sac; m.b.m., mantle-body-wall muscles; ov.o., oviduct opening; r.m., muscles radiating from ventral endosternite; tr.m., trophic muscles.

FIG. 18.—Ventral dissection, showing nervous system (adductor muscle removed). br., brain; C.I-VI, nerves to cirri; c.o.n., circum-oesophageal nerve; e., eye; l., labrum nerve; p., p', main and accessory peduncular nerves; pen., nerves to penis.

FIG. 19.—T.S. posterior end, showing discharge of peritrophic membrane. × 11.

FIGS. 20-22.—Successive stages in development of new peritrophic membrane, passing from behind forwards in same specimen as Fig. 19; all × 27.

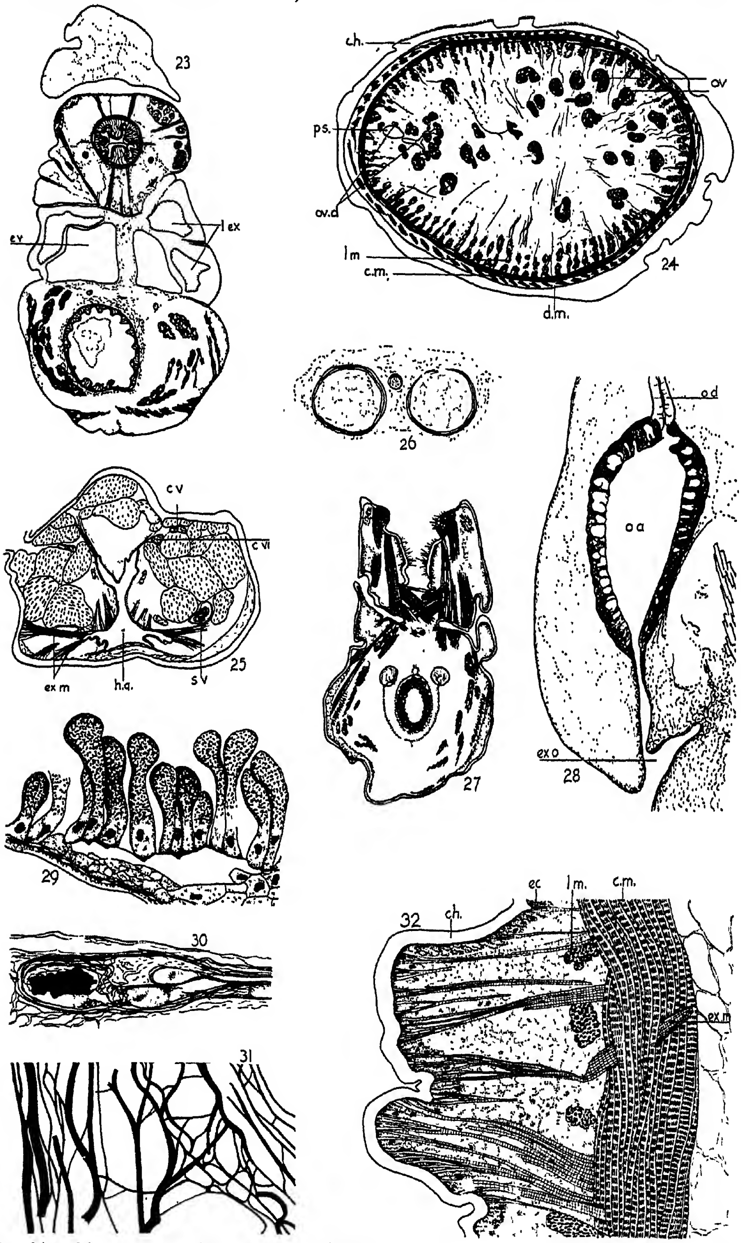


Fig. 23.—T.S. young specimen. × 22. (See Figs. 10 and 17 for angle of section.) l.ex., lateral excretory sac; ev., evacuatory sac.
Fig. 24.—T.S. peduncle. × 7½. ch., chitin; c.m., circular muscles; d.m., diagonal muscles; l.m., longitudinal muscles; ov., ovary branches; ov.d., oviducts; p.s., peduncular sinus.
Fig. 25.—T.S. thorax through hind-gut (h.g.), × 16. C.V-VI, nerves to cirri V and VI; ex.m., extrinsic muscles of hind-gut; s.v., seminal vesicle.
Fig. 26.—T.S. nerve cord, inter-ganglial region, × 76.
Fig. 27.—T.S. thorax, × 19, showing deep inter-cirral apodemes and muscles crossing from these to cirri.
Fig. 28.—T.S. oviduct atrium, × 5. od., oviduct; o.a., oviduct atrium; ex.o., external opening of oviduct, below cirrus I.
Fig. 29.—Portion of septum between excretory and evacuatory sacs, showing characteristic cells lining former, × 580.
Fig. 30.—L.S. eye and ophthalmic ganglion, × 132.
Fig. 31.—T.S. central region of peduncle

structure. At the same time, the histology quickly changes to the thin-walled mid-gut arrangement. This shows a lining of tall columnar epithelium cells, thrown into numerous low papillae filled with connective tissue. Next, more especially anteriorly, come scattered diagonal muscles lying in two series at right angles to each other; while around them is a compact layer of circular muscles, running continuously into the thicker layer of oesophageal circular muscles. Surrounding the mid-gut is a broad layer of parenchyma cells with conspicuous nuclei.

A sharp constriction separates the mid-gut from the "rectum," or hind-gut, whose transectional appearance is shown in Fig. 25. The cellular wall surrounding the delicate chitinous lining is extremely thin. From among its cells, extrinsic muscles radiate out to the body-wall.

A pair of many-lobed digestive diverticula lie laterally at the junction of fore- and mid-gut (Fig. 10, dig.). Each opens into the beginning of the mesenteron posterio-laterally by a fine, short duct. The epithelial cells lining the glands are cubical. The gland contents appear granular.

Peritrophic Membrane: Food accumulates in the mid-gut, separated from its epithelial lining by a peritrophic membrane—a thin chitinous secretion.

While one peritrophic membrane is being extruded through the anus (Fig. 19), the next is already being formed in the mesenteron (which, in the temporary absence of contents, is much constricted). Its development is most advanced at the anterior end, but it appears to be being formed throughout the length of the mid-gut. In passing from behind forwards, first occurs a region with nothing inside the columnar epithelium. Then a finely granular substance appears on the surface of some, then all, of the cells (Fig. 20). A little further forward this fills the whole lumen (Fig. 21). Then it becomes separated from the epithelium and a cavity appears in its centre (Fig. 22). At this stage, before it is distended with food, the membrane appears relatively thick. Its granular outer and inner boundaries take fuchsin stain. The intervening zone is pale and irregularly stained with the aniline blue of Mallory's.

Excretory System: The paired excretory organs are placed in the U-bend of the gut. Each consists of an outer lateral excretory sac and an inner evacuatory sac (Figs. 17, 23, 1. ex. and ev.).

Each lateral excretory sac is lined with granular yellow excretory cells of characteristic appearance (Fig. 29). No opening from lateral sacs was observed, but the walls separating them from the evacuatory sacs are thin.

Each evacuatory sac, next to its lining of thin epithelial cells, has a wall of anastomosing fibres similar to those occurring in the peduncle and to a lesser extent in other parts of the body.

The short excretory ducts pass from the evacuatory sacs to the openings on the maxillae. They consist of cubical epithelium, show chitinous linings, and have an internal diameter of about 15 microns. Judging from the position of their openings, these excretory organs are probably homologous with the maxillary glands in other groups of crustacea.

Reproductive System: The *testis* is a median structure lying closely in the U-bend of the gut. Dissections show it as a compact, lobulated, dull orange organ (Fig. 10, tes.). Sections show it to consist of a mass of irregularly-branching thin-walled tubes ramifying through compact parenchyma (Fig. 12), this latter being continuous with the connective tissue of the mid-gut wall. The tubes are packed with undifferentiated cells and the various stages of developing spermatozoa.

From each side of the testis arises a duct which soon expands to form a seminal vesicle. This during summer and autumn is a smooth, conspicuous whitish-coloured, convoluted tube, thin-walled and packed with sperms (Fig. 10, s.v.). Posteriorly it tapers, fusing with its pair above (ventral to) the anus, the resulting fine duct traversing the length of the penis.

The *ovary* lies embedded in the upper part of the peduncle, usually conspicuous because of the contained bright orange eggs (Fig. 24). Whether it is really a single or paired structure is obscured in the adult by the irregular, grape-like form.

From the ovary pass a number of tubes, which soon fuse anteriorly to form the two oviducts. Each of these is slender, its wall consisting of a single layer of tall, pale, apparently vacuolated cells, whose tiny nuclei lie close to their bases. In the adult the lateral diameter of the duct is ± 80 microns, its dorso-ventral diameter about twice this. The two oviducts converge, running up close to the muscle wall of the peduncle and into the capitulum, then passing into the anterior end of the body under the rostrum. Their subsequent course, through digestive glands and testis, is shown in Fig. 10 (ov.). Each expands into an oviduct atrium at the base of cirrus I (Fig. 28). Gland cells in the wall of this presumably secrete the matrix which binds the ova into ovarian lamellae. The atrium opens to the exterior by a narrow slit (Figs. 8 and 28, ov.o. and ex.o.).

Haemocoel: In this as in other cirripedes there occurs no closed vascular system, with vessels or heart. A haemocoel, in the form of irregularly anastomosing sinuses, occurs in the loose connective tissue surrounding the various organs.

Dorsal to the posterior half of the mid-gut lies a fairly extensive sinus, interrupted medianly by a connective tissue septum from food-canal to body wall. Around the U-bend of the gut connective tissue is more copious, but this is traversed by numerous smaller sinuses, chief of which is the peri-neural sinus. Small spaces among the connective tissue surrounding prosomal viscera converge anteriorly, passing into the mantle under the rostrum as a single sinus. This at first runs immediately in front of the oviducts (Fig. 24, p.s.), then turns back in the peduncle and forks.

Nervous System (Figs. 9, 10, 18).

The central nervous system consists of an anterior supra-oesophageal ganglion or "brain" connected by a pair of circum-oesophageal nerves to a short ventral cord.

Surrounding both nerve cord and nerves is a sheath, staining blue with Mallory's. Around the sub-oesophageal ganglion especially, this appears laminated, and around nerves in longitudinal sec-

tion it is clearly annulated. These features, together with the light purple colour that the enclosed nerve fibres stain, serve as useful criteria in tracing the finer branches of nerves amongst muscles. The larger nerves in cross-section are seen to consist of several bundles of fibres, each bundle surrounded by a thin blue-staining sheath.

The brain is a bilobed structure (Fig. 18, br.), histologically showing a considerable degree of complexity. From each lobe runs forward a stout peduncular nerve (Fig. 18, p.). This passes down along the junction between body and mantle, beneath the rostral sinus, receiving a composite lateral branch en route. Each nerve, after approaching an oviduct from above, swings round its outer side to enter the peduncle close behind it.

During the first part of their passage from the brain the peduncular nerves are connected by a sheet of tough tissue. Embedded in this are three extremely slender nerves, arising anteriorly from the brain (Fig. 18). The middle one of these is soon no longer traceable, but the lateral ones expand into ophthalmic ganglia placed close together. Anterior to them, sometimes in contact but at others well separated, lies an irregular mass of dense black pigment, the single median eye, without lens and of simple structure (Fig. 30).

Posteriorly from the lobes of the brain pass back the two long circum-oesophageal nerves. Each gives off a branch distally at the level of the oesophagus, and subsequently enters the front end of the sub-oesophageal ganglion.

The ventral nerve cord is obscurely double, its two elements being more or less fused in the ganglia, but separated by connective tissue and by a slender median nerve in the inter-ganglial regions (Fig. 26). There are four ganglia (Figs. 9, 18), innervating together no fewer than nine segments. Of these, the sub-oesophageal ganglion (s.o.), elongated and slightly bilobed, is the largest and most complex. From its lower surface arise the stout, paired adductor muscle nerves (Fig. 9, add. nv.). These at first pass down and forwards beneath the circum-oesophageal nerves (Fig. 10 ad.n.), running side by side medianly in the septum between the excretory organs, usually above the upper endosternite. They then diverge sharply, pass round the fore-gut on the outer side of the circum-oesophageal nerves, and sweep up to enter the adductor muscle close to its attachment to the scuta.

Each adductor muscle nerve, on approaching the fore-gut, has given off a slender branch which soon divides (Fig. 10). Of its bifurcations, the distal branch quickly enters mantle-body-wall muscles. The proximal fuses with the branch from the circum-oesophageal commissure, the resulting nerve (Fig. 10, ped.n') passing forwards among the lobes of the digestive gland to fuse with the main part of the peduncular nerve close beneath the eye.

From the region of the sub-oesophageal ganglion also arise five other pairs of nerves (Fig. 9). Those supplying the mandibles originate, not from the ganglion itself, but a short distance in front of it from the circum-oesophageal commissure. The maxillulary (mxl.n.) and the maxillary (mx.n.) nerves pass up actually from the anterior end of the ganglion. The former diverge considerably,

soon forking, while the latter converge slightly. Each breaks into several branches which enter the muscles of its appendages.

The stout cirrus 1 nerves leave the sides of the ganglion, passing first slightly back and out, then swinging forwards to run up into the cirri (Fig. 18, C.I.). From the base of each a branch goes downwards (Fig. 9, mus.n'), closely following the bend of the oviduct for some distance, and finally branching to supply the lateral body-wall muscles. A further pair of nerves (Fig. 9, mus.n.I) passes outwards from the ganglion close in front of those to cirrus 1. Each soon bifurcates, one half passing up, the other down, into the muscles at the base of the first cirrus.

Similarly with the second and third ganglia (each of which innervates one segment only) there occur both main cirrus nerves running up into the limbs (C.II and III), and also more slender anterior nerves, branching to supply the muscles at the limb bases (mus.n.II and III).

The last ganglion is elongated, a slight constriction indicating its composite nature. From it arise cirri nerves IV, V, and VI, of which only the first pair is accompanied by the additional pair of basal limb-muscle nerves (mus.n.IV). Nerves IV, just before leaving the body, send in branches which fuse with V (Figs. 9, 18).

Nerves V and VI leave the ganglion terminally, the former uppermost, running back for a considerable distance in the body before entering their cirri. Immediately prior to leaving the body, nerves VI give off proximally slender penis nerves (Fig. 18, pen.). These pass along each side of the hind-gut, close above the tapering seminal vesicles. The latter fuse at the base of the penis to form a single sperm-duct, at the sides of which the nerves pass up the penis.

As in Crustacea generally, a visceral or sympathetic nervous system is present. This consists mainly of slender median nerves arising from each ganglion. From the hinder margin of the brain several strands pass directly to the underlying oesophagus, the stoutest of these running up its outer wall towards the labrum (Fig. 18). Slightly stouter nerves originate from the inner bases of the mandibular nerves (Fig. 9, p.o.n.). These bifurcate, their distal halves passing to the fore-gut muscles, their proximal halves fusing medianly, but soon breaking up to form a delicate plexus in the posterior oesophageal wall.

Dorsal nerves pass down from the ganglia of the ventral cord —two from each of the first three, four from the last, of which the final one is directed backwards (Fig. 9, sym.n.). All these lie in loose connective tissue, and are traceable in serial sections as far as the walls of the food canal.

Discussion.

From the foregoing description, let us consider certain features of *Pollicipes spinosus* as compared with those of other barnacles. To begin with, there is the feeding technique, with the absence of the habit of actively extruding and withdrawing the cirri. The precise dwelling place of *P. spinosus,* where water surges violently along inter-tidal rock channels, would doubtless bring a much greater number of food particles to the cirri-net than would any currents

the animal itself could create. Perhaps this species has never had a more active feeding mechanism. The wide occurrence, however, of the habit of almost rhythmically extruding and withdrawing the cirri, among both sessile and stalked barnacles, would seem against this. More probably it was superfluous in the habitat where *P. spinosus* occurs, and has secondarily been lost.

Not only in feeding, but in all its requirements this species seems unusually sluggish for a cirripede. In that the irregular blood circulation is considered to be caused by the general body movements, perhaps with a resultingly low metabolic rate in *P. spinosus* the extremely slow growth-rate is correlated.

For in its rate of growth this species seems remarkable among cirripedes. Moore (1944, p. 331) records that the operculate *Elminius modestus* took 2½–3 months from time of attachment to the production of nauplii; Darwin (1851, p. 63) states that the yawl of the "Beagle," after 33 days in the sea, had several specimens of *Conchoderma virgata* already sexually mature; and Gruvel (1905, p. 426) maintains that the growth-rate of cirripedes generally is very rapid, pedunculates usually increasing more quickly than operculates, typically by nearly a millimeter a day until adult size is attained. Compared with this, the approximate five years that this species takes to reach sexual maturity stands in striking contrast.

In its anatomy, as compared with other cirripedes, *P. spinosus* shows no particularly noteworthy features. The adult barnacles have revealed no vestige of antennae, compound eyes, a heart, an abdomen with abdominal limb rudiments, or any of the other characters by whose absence adult thoracic cirripedes differ from less specialised crustaceans. There is, however, in its structure an absence of specialised features which collectively seem indicative of a comparatively primitive state. For instance, the cirri, unlike those of many pedunculates and operculates, are all of approximately equal length, with the first pair placed close to the second. The digestive glands consist of one pair of organs only, whose several lobes are all histologically similar. The mid-gut lacks regional structural specialisation. Branches of the testis do not ramify among the other organs, or into the limb bases. Branchial filaments have not been developed from the surface of the body or mantle lining. There is no trace of a boring, parasitic, or other specialised habit. The elaborate gastro-ophthalmic nerve plexus, occurring in certain operculates, is absent. Certain other features of the nervous system, such as the detailed segmental arrangement of the nerves, perhaps show a closer similarity to those of a generalised crustacean such as *Chirocephalus* than is shown by other cirripedes. But in the absence of sufficiently full accounts for other barnacles one hesitates to put much weight on such comparisons.

Dwarf males are absent in *Pollicipes spinosus* and other members of the genus, present in the related *Calantica, Smilium, Scalpellum, Ibla,* and reputedly in *Protomitella.* Broch appears to consider dwarf males as a basic feature of scalpelliform cirripedes. He regards his new genus *Protomitella* as primitive in this respect, considering *Pollicipes* as a specialised sideline from which dwarf males

have been lost (Broch, 1921, p. 247). But, even assuming the validity of his *Protomitella,* does a wider survey of the cirripedes permit such a view? Only hermaphrodite individuals occur throughout the Balanidae, Verrucidae, and Lepadidae; while the remaining section of thoracic cirripedes, the Scalpellidae, shows many instances of this condition—for example, the genera *Pollicipes*, *Smilium*, and *Scalpellopsis*. The presence of complementary males associated with large hermaphrodite forms is not universal among any main section of cirripedes, but is scattered amongst various scalpellid species and genera. The unisexual condition is comparatively rare, occurring only in occasional scalpelliforms and certain *Ibla* species. Incidentally, the presence of dwarf males seems rather closely associated with a solitary habit. This suggests that their reduced parasite form has evolved in cases where cross-fertilisation could otherwise not readily occur. So it would seem that the weight of evidence is against Broch's hypothesis. Instead, it appears more logical to regard the totally hermaphrodite condition of *Pollicipes* as the typical cirripede state and the presence of dwarf males in various allied genera as a secondary future.

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Systematic and Biological Account of the New Zealand Mygalomorphae (Arachnida).

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Introduction.

The Mygalomorphae is a sub-order of the order *Araneae*. This sub-order is synonymous with Eugene Simon's (1892) family Aviculariidae. It is a group which possesses affinities with the segmented Liphistiomorphae as well as with the more advanced Araneomorphae. An attempt has been made to survey the Mygalid spiders in this Dominion. The families Ctenizidae, Dipluridae and Migidae are represented in New Zealand, and members of these three families have been available for study. A survey has been made of all the New Zealand species including those which have been previously described. These latter have been redescribed from actual specimens identified as belonging to the same species and from the same locality. Each species has been dealt with under the headings of taxonomy, biology and distribution. The range in distribution given is likely to be extended with a little more investigation of those parts of the country not visited.

The earliest descriptions of New Zealand Mygalomorph spiders were those of Koch (1873–4), Cambridge (1873, 1877, 1879), and Simon (1892). These descriptions were usually based on an examination of one or two spiders and the holotypes are unfortunately not to be found in New Zealand. Often no mention has been made as to the depositing of holotypes at all, and for convenience neotypes of most of the predescribed species have been placed in the Otago Museum.

New Zealanders who have dealt with the systematics of this group are Goyen (1886, 1890, 1891), and Urquhart (1893). Hogg (1901), in a survey of Australasian Mygalomorphs deals with the New Zealand members of the group. He recognises five genera, one a new one. Hutton (1904, pp. 236–7) lists six genera, which consist of Hogg's five and one (*Cteniza*) which had been previously proved a synonym. The latest account is that of de Dalmas (1917), who doubts the validity of Hogg's new genus, but otherwise his list is similar to the latter's. Several new species have been described in this paper, including two which probably also constitute new genera.

Apart from Gillies' work on the habits of *Arbanitis gilliesii* (1875, pp. 222–262), and that of Gatenby (1911, pp. 234–240) on *Migas distinctus* very little biological study has been done on the group in New Zealand.

Since several genera are to be considered, it may be helpful to give some short account here of the salient features of each genus; features by which they may be readily recognised. Spiders belonging

to the genus *Arbanitis* all live in burrows in the ground. They are large, brownish spiders, comparatively slow in movement. The burrow is typically closed with a trap-door except in *Arbanitis huttoni,* which has an open burrow. *Cantuaria* is very like *Arbanitis* in appearance and has a trap-door to the burrow. *Migas* species are usually small spiders which have a stunted appearance when compared with the other genera. A trap-door is always present covering the burrow. *Porrhothele* and *Hexathele* are large spiders which live in striking tubular webs under stones on the ground or under the loose bark of trees. They are swiftly moving spiders with characteristically long superior spinnerets, and often they have a brightly coloured (red or orange) prosoma. *Hexathele* may be distinguished from *Porrhothele* by the possession of two additional spinnerets, making a total of six.

I have to thank the following people for giving, sending or lending me material:—

Professor B. J. and Mrs. Marples for N.Z. Mygalids they had collected, and for allowing me to examine some European *Nemesia* specimens and a *Heptathela* (Liphistiomorphae); Mr. Sorensen (Invercargill), Mr. Sanderson (N. Auckland), Murray Smith (Dunedin), Alan Meikle (Oamaru), Mr. MacFarlane (Christchurch) and others, all of whom sent me many spiders.

Also thanks to the Auckland War Memorial Museum, the Dominion Museum (Wellington), Canterbury Museum (Christchurch), and the Wanganui Museum for letting me examine or for sending me Mygalomorph spiders in their possession.

In dealing with the Systematics of the group something must be said of the methods used in determining the characters which are regarded as having specific value. In the past the arrangement of the eyes has been largely used in classification depending on the direction of the curve of the anterior and posterior rows of eyes. Much discrepancy is noticed in different authors' descriptions. The reason for this divergence of opinion is made obvious if a semicircular object is considered. When this is looked on from various directions and at differing distances the curve appears to change in degree of convexity. Likewise with the rows of eyes in spiders, for unless they are looked at in a constant position and from the same direction their curve will appear to vary. So, to make this a worth-while specific character, the method employed here was to examine the spider always with the anterior end towards and directly below the observer, giving a fairly constant angle of observation. To obtain as flat a plane as possible and prevent tilting, the abdomen and all the legs were removed. It is to be noted that eye arrangement is not always a dependable specific character as the spaces between eyes may vary with age (de Dalmas, 1917).

In all cases mature spiders were examined and description (except in the case of one or two males and one female) is based on no less than three members of the species and in most cases on many more than this. Where males were available, the structure of the palpal organs and tibiae of the first leg were good specific characters. The spines and tarsal claws form the other main structures used in systematic consideration.

Explanation of Some Terms Used.

There are several terms which are constantly used in Systematic descriptions with widely varying meanings according to different authors. The following is a dictionary of the terms used here, listed with their appropriate meanings:—

Cheliceral Groove.—Groove on the basal segment of the chelicera in which the fang fits in the resting condition.

Clypeus.—That part of the cephalothorax lying between the front row of eyes and the base of the chelicerae.

Fovea.—Indented line in the middle of the cephalothorax.

Procurved.—Applied to a curved row with the concavity in front.

Rastellum.—Group of stout teeth at the extremity of the basal joint of the chelicera.

Recurved.—Curved row with concavity behind.

Scopula.—Area covered with fine hair. May be cheliceral, maxillary or on the tarsus or metatarsus of the legs.

Seta (or Bristle).—Stouter than a hair but less stout than a spine and usually not articulated at the base.

Sigillae.—Small round areas occurring in pairs on the opposite edges of the sternum.

Spine.—Stout basally articulated structure.

Venter.—Ventral surface of the abdomen.

Spiderling.—Newly hatched spider in the cocoon, differing from subsequent instars.

The following abbreviations have been used throughout:—

With Regard to Eye Arrangement—

f.r.—front row.	h.r.—hind row.
f.m.e.—fore median eyes.	f.l.e.—fore lateral eyes.
h.m.e.—hind median eyes.	h.l.e.—hind lateral eyes.

Measurement—

cl.—cephalothorax length.	cb.—cephalothorax breadth.
al.—abdomen length.	ab.—abdomen breadth.

Sub-order MYGALOMORPHAE.

KEY TO THE NEW ZEALAND SUB-FAMILIES OF THE SUB-ORDER MYGALOMORPHAE.

1.	Rastellum	Ctenizinae	
	No Rastellum	..	2
2.	Two sternal sigillae	Miginae	
	Six sternal sigillae	..	3
3.	Six spinnerets	Hexathelinae	
	Four spinnerets	..	4
4.	Web-weavers. Posterior spinnerets very long	Macrothelinae	
	Burrowers. Posterior spinnerets seldom longer than half the length of the abdomen	Diplurinae	

Family CTENIZIDAE.

Chelicerae with rastellum. Maxillary lobes wanting. Three claws. Upper claws similar, pectinate in a single or double row. Four, rarely six, comparatively short spinnerets; anterior pair more or less approximated. Thoracic groove variable. Eight eyes. (Petrunkevitch, 1928).

Sub-family CTENIZINAE.

Lip free. Thoracic groove transverse. Sternum two-six sigillae. Four spinnerets. Upper claws pectinate in either a single or a double row.

Genus Arbanitis Koch, 1874.

The genus was established by Koch (1874) as *Pholeuon* and later changed by him to *Arbanitis* (p. 491). The type species for the genus *A. longipes* is not found in New Zealand.

The genus is characterised by the possession of six sigillae on the sternum; the upper claws are pectinate in a single row, and there is a scopula of fine hair on the inferior surface of the metatarsus and tarsus of the palps and the first and second pairs of legs. The spider always digs a burrow.

Arbanitis gilliesii (Cambridge, 1877).

Nemesia gilliesii Cambridge, 1877. T.N.Z.I., x, p. 281.

Arbanitis gilliesii Simon, E., 1892. "Histoire Naturelle des Araignées," p. 115. Hogg, H. R., 1901. P.Z.S., p. 233. de Dalmas, 1917. Ann. Soc. Ent. Fr.

The correct specific form of "Gillies" should be "gilliesi". However, since it was originally published as "gilliesii" this must be retained (Article 19, Rules of Zoological Nomenclature). Although Cambridge omits to mention this, the holotype for this species is probably in the British Museum. Nevertheless it has been thought necessary to establish a neotype which is deposited in the Otago Museum. Cambridge described both the female and male thoroughly (*loc. cit.*), and the following summary of the main characters differs in no way from his account.

Female.

Cephalothorax: Lightish brown, hairy, procurved fovea.

Abdomen: Fawn, with dark brown speckled pattern.

Chelicera: Rastellum. Eight large teeth on inside of cheliceral groove and four small teeth on outside. A thick scopula of orange hair on outside of the outer row of teeth.

Palp: One terminal claw. Tarsus with scopula of fine hair.

Maxilla: Scopula of orange hair anteriorly. Anterior angle of the inferior surface studded with spines (Pl. 55, Fig. 1).

Labium: No spines. Some setae (Pl. 55, Fig. 1).

Sternum: Six orange sigillae.

Venter: Fairly distinctive pattern in dark brown.

Spinnerets: (1) Unsegmented. (2) Three segments.

Eyes: F.r. strongly procurved. h.r. recurved. f.m.e. their diameter apart. x 1½ diameter from f.l.e. H.l.e. x 2 diameter from f.l.e. H.m.e. of pearly lustre x 1 diameter from h.l.e. and x 2 diameter from f.m.e. (Pl. 56, Fig. 25).

Tarsal Claws of First Leg of Right Side: Superior claws with two pectinations. Inferior claw without pectination. (Pl. 57, Fig. 39).

Dimensions: The average length of the spider from the front edge of the cephalothorax is 19·0 mm., and the width of the cephalothorax is 7·5 mm.

Male.

Cephalothorax: Very broad, light brown, hairy. A few setae in line from the fovea to the ocular area and on the clypeus. Fovea straight with radiating lines well marked.

Abdomen: Creamish colour with dark speckled pattern. Covered with long dark setae.

Chelicera: Rastellum. Very dark brown with reddish-brown fang. Four large and four smaller teeth on inside of cheliceral groove and eight small ones on inferior outside half. Slight scopula on inside and thicker orangish one on outside of furrow.

Palp: Tibia and tarsus modified as copulatory organ. Bulb long and pointed. Alveolus edge covered with a mass of short spines in basal part. Short spines on proximal tarsal joint. (Pl. 58, Fig. 54).

Tibia of First Leg: U-shaped modification (Pl. 58, Fig. 64).

Maxilla: Anterior angle of the inferior surface covered with spines. Scopula of orange hair (Pl. 55, Fig. 5).

Labium: No spines. Stout setae on anterior angles.

Sternum: Rectangular. Six sigillae (Pl. 55, Fig. 5).

Venter: Pattern in dark brown. Genital operculum creamish.

Eyes: f.r. strongly procurved. h.r. strongly recurved. f.m.e their diameter apart x $1\frac{1}{2}$ diameter from f.l.e. H.l.e. x 2 diameter from f.l.e. H.m.e. (not pearly) about x $\frac{1}{2}$ diameter from h.l.e. and x 1 diameter from f.m.e.

Dimensions: cl. = 6·0 mm. cb. = 7·0 mm. al. = 6·0 mm. ab. 4·0 mm. Leg-lengths: i = 24·0 mm. ii = 22·0 mm. iii = 20·0 mm. iv = 25·0 mm.

Biology.

Arbanitis gilliesii is the largest of the true trap-door spiders in New Zealand. The nests of this spider have been fully described by Gillies (1875), and some of his original nest material is in the Otago Museum. The depth of the burrow varies from 8–14 inches, the width is from $\frac{1}{2}$–1 inch, and the trap-door is of the wafer type. Nests which were collected from Palmerston South in April, 1941, were in an open field leading back to other nests under pine trees.

Arbanitis is characterised by a rastellum on the chelicera, and this is used in digging the burrow. The palps and first two pairs of legs also help to scrape the earth away. *Arbanitis* excavates the whole burrow before any lining with silk commences. The door is constructed right across the opening and it is after this that the lining begins. One concludes this by observing the movements that go on under the closed door of the burrow. The spider then bites round two-thirds of the door leaving the remaining third to act as a hinge. This kind of hinge does not allow the door to be opened right back, and if opened it will close itself. The stance of all Mygalid spiders in the burrow is with the first two pairs of legs directed forwards and the last two pairs directed backwards.

The spider does not spin any web to catch its prey, but depends on its deftness of movement to obtain food. The movement of an insect or other small arthropod across the trapdoor is sufficient to stimulate the spider into opening the door and springing upon the disturber, which it then drags inside to consume. The spider seldom leaves the nest to capture prey, but has been seen on occasion to pursue an insect which had escaped from the first pounce. As it rushes at the victim the fangs are held erect, and these pierce the prey, injecting poison from the poison gland. The spider usually holds the prey thus with the aid of the palps. Only liquid food is absorbed, and presumably the next stage is the secretion of diges-

tive juices on to the victim. The maxillary glands opening on the maxillae and the rostral gland are probably active here. During this time the spider is holding the prey and a rhythmic pressing between the jaws and palp is in progress. Whether this indicates that food is being sucked up the pharynx or whether it aids the secretion is not clear. Probably the food is taken up as soon as it is in a liquid state. Usually the prey is chewed up in the jaws, but sometimes a complete empty shell of the victim is left.

This process of external digestion or partial digestion takes quite a long time. A young *Arbanitis* given a slater outside the burrow took four hours from the time of piercing it with the fangs to the time of discarding it as a dry, crushed mass. The spiders will not touch dead animals, and movement or some sort of vibration seems to be essential to begin the actions which fulfil the food procuring instinct.

After a meal the debris is sometimes brought up and left outside the burrow or flicked from it with the palps, but usually it is to be found at the base of the burrow. Often there is a whole branch full of debris coming off from near the base and sealed off with silk from the main passage of the burrow. One of these branchfuls was examined and found to contain the remains of four different kinds of beetles, carabid beetles, a weevil, a large number of *Odontria striata*, a large beetle, and another smaller one. Also among the debris was a caterpillar, a small fly, and the chelicera of a spider of the same species.

The male spider is as large as a mature female, but not so large as the largest of these. Evidence obtained from German owl stomach contents (see later) shows that males are commonest from the months of April to June. Some young spiders were collected in April also.

Distribution.

Arbanitis gilliesii specimens were collected from Palmerston and others were sent from Oamaru and Kakanui. The strictly local distribution of any Mygalomorph is very marked.

Mygalid spiders found among the stomach contents of German owls by Marples (1942, p. 242) gave some valuable distributional facts as well as some insight into the life of the male spiders. All the spiders found in this way were of the male sex. The owls feed at night, and sometimes there were as many as 30 spiders in one owl. It certainly looks as though males are not so scarce as we have been led to believe they are. They leave their burrows at night; the very fact that no female has ever been found in these owls strongly suggests that she does not leave her nest.

Distributional information from this source extended the known range of *Arbanitis gilliesii* into Central Otago.

Arbanitis huttoni Cambridge, 1879.

Arbanitis huttoni Cambridge, O. P., 1879; P.Z.S., p. 682.
Arbanitis huttoni Goyen P., 1891; T.N.Z.I. xxiv, p. 255.
Arbanitis huttoni Hogg, H. R., 1901; P.Z.S. p. 236. de Dalmas, 1917; Ann. Ent. Soc. Fr.

Cambridge described the male *Arbanitis huttoni* (*loc. cit.*) and some 12 years later Goyen described the female and its burrow. In

both cases any mention of a type specimen is omitted, so a neotype has been deposited in the Otago Museum.

Arbanitis huttoni differs from *A. gilliesii* in

1. Smaller size.
2. Smooth cephalothorax.
3. Larger number of spines on the maxilla.
4. Venter marking.
5. f.r. eyes are not so strongly procurved.
6. More pectination on the tarsal claws.
7. Bulb of the male palpal organ is much blunter.
8. Habit. *A. huttoni* has no trap-door to the burrow.

Female.

Cephalothorax: Brown, fovea straight.

Abdomen: Light brown with pattern in dark brown.

Chelicera: Rastellum. Six large teeth on inside of groove. Seven to eight small teeth on inferior half of outside of groove. Scopula of brownish hair on the outside.

Palp: One claw. Scopula on inferior-surface of tarsus which bears four to five spines.

Maxilla: Half inferior surface covered with spines. Scopula of orange hair anteriorly. (Pl. 55, Fig. 2).

Labium: No spine. Setae.

Sternum: Covered with setae. Six sigillae (Pl. 55, Fig. 2).

Venter: Very characteristic marking.

Eyes: f.r. procurved. h.r. slightly recurved. f.m.e. hardly their diameter apart. x 1 diameter from f.l.e. which are largest. h.l.e. x $\frac{3}{4}$ diameter f.l.e. and this distance away from f.l.e. H.m.e. of pearly lustre x $\frac{1}{2}$ diameter h.l.e. and this distance away from h.l.e. (Pl. 56, Fig. 26).

Tarsal claw: Superior claws four to five pectinations (Pl. 57, Fig. 40).

Dimensions: cl. = 6·0 mm.; cb. = 5·0 mm.; al. = 9·0 mm.; ab. = 5·5 mm.

Male.

Cephalothorax: Varying from pale to deep chocolate brown. Fovea recurved. Short hairs found especially in the furrows which radiate from the fovea.

Abdomen: Fawnish or cream patterned in dark brown.

Chelicera: Rastellum. Six large teeth on inside of groove. Three to four smaller ones on outside. Scopula of brown hair on outside of this again.

Palp: Bulb with short, blunt point. Alveolus bespined at base of bay, then a gap with no spines. On top of the bay a few longish spines. Tarsal and tibial joint with spines on dorsal surface (Pl. 58, Fig. 55).

Maxilla: No spines. Scopula of orange hair anteriorly (Pl. 55, Fig. 6).

Labium: No spines.

Sternum: Fairly rectangular in shape. Six sigillae (Pl. 55, Fig. 6).

Venter: Definite pattern like the female.

Eyes: f.r. procurved. h.r. recurved. f.m.e. their diameter apart and x 1 diameter from f.l.e. These are the largest eyes and are x $\frac{3}{4}$ diameter from h.l.e. H.m.e. of pearly lustre x $\frac{1}{2}$ diameter of f.l.e. and adjoining these.

Dimensions: cb. 4·5 mm.; cl. 3·5 mm.; al. 5·0 mm.; ab. 3·0 mm.

Legs: 4123.

Arbanitis huttoni sub-sp. **stewarti** nov.

This spider differs constantly from *A. huttoni* in the following points:—

Female.

1. General darker colouring, the cephalothorax is black-brown.
2. Scopula on tarsus of first and second legs is not well marked and still less obvious on the metatarsus of these legs.
3. Smaller number of teeth in the outer row of the cheliceral furrow. Five to six little ones. (c.f. *A. huttoni* has eight small ones).
4. The thoracic fovea is very slightly recurved.
5. The fore-median eyes are less than their diameter apart.

Male.

Apart from darker colouring this agrees with *Arbanitis huttoni* male.

The habit of the spider is similar to *A. huttoni* for it has a silk lined burrow without a trap-door.. However, these constant variations seem to necessitate the formation of a sub-species *Arbanitis huttoni stewarti.*

The following is the description of an isolated male cephalothorax found at Rakiahua, Stewart Island.

Cephalothorax: Orangish brown. Fovea damaged.

Chelicera: Rastellum. Six large teeth on inside. Five small ones on inferior half of outside of furrow. Scopula of orangish hair on outside of this.

Palp: Bulb with a long, thick, blunt point. Alveolus studded with short spines at the base. Four long spines at the top of bay. Tarsus and dorsal upper surface of tibia covered in large spines.

Maxilla: Few very short spines on anterior angle of inferior surface. Orange scopula anteriorly.

Labium: No spines. Some long setae.

Sternum: Six sigillae.

Eyes: f.r. very strongly procurved. h.r. recurved. f.m.e. hardly their diameter apart x 1 diameter from f.l.e. These are largest and are about x $\frac{3}{4}$ diameter from h.l.e. H.m.e. smaller (x $\frac{1}{2}$ diameter h.l.e.) of a pearly lustre x 1 diameter from f.m.e.

Dimensions: cl. = 7·0 mm.; cb. = 5·5 mm. [cf. *A. huttoni*—cl. = 4·5 mm.; cb. = 3·5 mm.] Leg lengths, i, = 26·0 mm.; ii, = 24·0 mm.; iii, = 20·0 mm.; iv, = 28·5 mm. [cf. *A. huttoni*—17·0 mm.; 16·0 mm.; 12·0 mm.; 17·5 mm.]

This specimen possesses the characteristic features of *Arbanitis* but differs from *A. huttoni* in the following features:—

1. Greater size and different colouring.
2. Bulb of palpal organ is blunter though more tapering.
3. Spines on maxilla.
4. Legs are better provided with setae and spines.

It differs from *A. gilliesii*—

1. Bulb of palpal organ not tapering to a point.
2. Presence of spines on tibia of palp.
3. Fewer teeth in cheliceral furrow.

Is this the male of another *Arbanitis* species, or is it the usual Stewart Island sub-species of *A. huttoni* grown to this size due to some growth upset? It is better to regard the latter as the more probable explanation as ordinary mature females were found further up the river. The increase of setae on the legs and the presence of spines on the maxillae may be consequent on the size increase.

Biology of A. huttoni.

Although the Mygalomorphs are commonly referred to as the "Trap-door" spiders not all of them construct a trap-door and some do not even burrow in the ground. *Arbanitis huttoni* has a burrow, but this is not covered with a trap-door. The nest is usually but not invariably branched. The main opening is quite conspicuous, with the silk lining protruding round the mouth, while the side branch is narrower and its external opening is generally more or less concealed by loose earth, or sometimes a flap of silk, the latter suggesting a trap-door. Burrows are found on banks near bush or on the bush floor. They tend to be most numerous where the soil is well held by roots, or if it is very wet and leafy they may be under logs. In digging out *A. huttoni* the spider was often found in the side branch, suggesting that this was used for escape purposes.

The average depth of the burrow is from 4–6 inches, with a diameter from 6–10 mm. The side branch may come off anywhere above the first three or four inches. To determine any relationship that may exist between the size of the spider and the diameter of the burrow, 46 spiders were taken from measured burrows and their cephalothoracic widths noted. For every 0·5 mm. increase in burrow width an average of the cephalothorax widths was taken. This showed that spiders up to 4·0 mm. in diameter lived in burrows of regularly varying diameter. The spider seldom exceeds 4·0 mm. in diameter and spiders of this width are found, on an average, in holes ranging in diameter between 9·0–14·0 mm. The largest cephalothorax measured was 5·0 mm. across, and this spider was from a 15·0 mm. hole.

The method of excavation of the burrow is the same as that of *Arbanitis gilliesii* but no trap-door is constructed. Male spiders seem much rarer than the females and many authors have thought that they may have a different type of nest from the female, or have no nest at all. *Arbanitis huttoni* males, however, have been found in nests similar to the females. That these truly belong to the male and are not just disused female nests is certain, since males kept in jars have built their own nests. The male spiders do not die after

the mating season. Unless circumstances force the female to leave her nest it is unlikely that she ever does so. A small area was kept under observation for eight months, and apart from small new nests coming into it little change in position of the burrows was noticed. Frequent relining of the nest with silk is essential to keep it firm and open. Presumably the spider enlarges the nest at intervals to keep pace with her own growth in size.

Food debris is often found at the sides of the burrow near the bottom, worked into the lining and covered over with silk. The spiders are most active in the spring and summer when there is an abundance of food available. In winter they seem to undergo a kind of hibernation. Spiders dug out of their burrows at this time were always in a somnolent condition at the bottom of the burrow, and they offered no resistance when picked up. In spring or summer, on the other hand, they will rear up in a defensive attitude when touched (although often they remain immobile for a while). Sealed up nests are not uncommonly found during the winter period. In *A. huttoni* the silk lining round the mouth of the burrow is brought together from two sides, giving the appearance of a trap-door. The significance of this sealing up is not understood (Gillies, 1875), but it would certainly have a protective function and also help to maintain an even temperature.

The male *A. huttoni* is usually smaller than the female, with a smaller abdomen and longer legs. Males have been collected between the months of December and June inclusive. This time coincides with that in which eggs and young are found, so may be taken as constituting the reproductive season.

From November till the end of March, cocoons were found suspended from the side near the bottom of the burrow. The cocoon is a flat sac and consists of a thin layer of silk containing the eggs overlain by a coarser layer. In *Arbanitis huttoni* the number of eggs in each cocoon is approximately 18 to 20, the diameter of an egg being 1·5 mm. About five weeks after laying the spiderling hatches. This is very smooth and quite hairless and has no eyes. The abdomen shows the remnants of at least five segments in front of the anal tubercle. The spiderling moulted within 48 hours (23/12/41). The spider of the first instar is 3·0 mm. long; it is hairy and the eyes are present although no pigment develops at first. It is very inactive and does not feed. Just over a month later (27/1/42) this moults to produce the second instar form. This almost immediately becomes active: it is hairy, with a bluish cephalothorax and a pink abdomen. From the time they reached the first instar three of these spiders were kept in a glass dish with damp cotton wool one side and earth the other. Up till the time of reaching the second instar they kept on the cotton wool, but after this moved on to the earth, and a few days later they dug their burrows and lined them with silk. From now on they are typical *Arbanitis huttoni* specimens and the spines on the maxillae and legs are well developed. The length of the spider now is 3·5 mm. and the cephalothorax width is 1·0 mm. The diameter of the first burrow is about 2·0 mm.

Distribution.

Arbanitis huttoni was collected from the Town Belt, Dunedin, at all seasons of the year. Specimens were also collected from Frazer's Gully, Mt. Flagstaff (Dunedin), Goat Island (Otago Harbour), Papatowai and Taieri Mouth. *Arbanitis* was the only genus found on Stewart Island during a short stay there. The nests were usually to be found on the bush floor and extended with the bush right down to sea level.

From the German Owl material, *A. huttoni* specimens were found from Riverton, Owaka, Balclutha and Invercargill, all south of Dunedin.

The genus *Arbanitis,* which is represented in Australia and New Zealand, has so far been found only in the South Island of New Zealand.

Arbanitis collensis n.sp.

The holotype is placed in the Otago Museum, and paratypes will be forwarded to other Museums if so requested.

Female.

Cephalothorax: Light brown. Fovea straight.

Abdomen: Very definite fern leaf pattern.

Chelicera: Rastellum. Six (to seven) large teeth on the inside of the groove and five small teeth on the outside.

Palp: One claw. Scopula on inferior surface of tarsus.

Maxilla: Few spines on anterior angle of inferior surface. Orange scopula of hair anteriorly. (Pl. 55, Fig. 4).

Labium: No spines.

Sternum: Fairly rectangular. Six sigillae. (Pl. 55, Fig. 4).

Venter: Mottling in chocolate brown.

Eyes: f.r. procurved. h.r. recurved. f.m.e. not their diameter apart ·x1 diameter from f.l.e., which are the largest eyes and are x $\frac{3}{4}$ diameter from h.l.e. H.m.e. small, of pearly lustre. (Pl. 56, Fig. 28).

Tarsal claws of First Leg: Anterior superior claw with several pectinations. Posterior superior claw with two large pectinations (Pl. 57, Fig. 43).

Dimensions: cl. = 7·0 mm. cb. = 5·0 mm. al. = 11·0 mm. ab. = 6·0 mm.

This differs from *A. huttoni* in the following points:—

1. Abdominal marking; but it is conceivable how one may be derived from the other by increase in the pigmented area.
2. Difference in venter markings. This is particularly noticeable as *A. huttoni* has such a constant pattern.
3. Fewer spines on the maxillae.
4. Fewer cheliceral teeth in outside row.
5. No setae on tarsus I and II (cf. *A. huttoni* has setae on outside of tarsus I and II).
6. Tarsal claw pectinations.

No males were collected. This spider came from Bench Island and was found in branched tubes under logs. The specific name is derived from Coll, the other name for the island.

Arbanitis marplesi n.sp.

The holotype is placed in the Otago Museum.

Female.

Cephalothorax: Pale brown. Hairy. Procurved fovea.

Abdomen: Very light brown, with a dark median dorsal stripe with indications of three pairs of lateral branches coming from it.

Chelicera: Rastellum. Ten teeth on inside of the furrow, eight on the outside opposite and below the fifth inside. Four small median teeth between the base of the two rows. Scopula of hair on the upper outside half of the chelicera.

Palp: One claw. Tarsus with scopula of fine hair. Two bristles at base of tarsus.

Leg IV: Patch of short bristles on anterior inside edge of femur.

Maxilla: Anterior angle of inferior surface studded with spines (Pl. 55, Fig. 8).

Labium: No spines.

Sternum: Six sigillae (Pl. 55, Fig. 8).

Venter: Very pale with no distinct pattern. Lung books are white and conspicuous.

Eyes: f.r. procurved. h.r. strongly recurved. f.m.e. x $1\frac{1}{2}$ diameter apart and this distance from f.l.e., which are the largest and x 2 f.m.e. H.l.e. x $\frac{3}{4}$ diameter of f.l.e., and this diameter from the f.l.e. H.m.e. of pearly lustre x $\frac{1}{2}$ h.l.e. and this distance from the h.l.e. (Pl. 56, Fig. 29).

Tarsal claw: One large pectination on superior claws. (Pl. 57, Fig. 42).

Dimensions: cl. = 7·0 mm. cb. = 5·0 mm. al. = 9·0 mm. ab. = 6·0 mm.

This species would seem to have possible affinities with *A. gilliesii;* however, the following points of difference may be noted:—

1. Pattern on the abdomen.
2. Larger number of teeth in the cheliceral furrow in this species.
3. Absence of pattern on the venter.
4. Difference in eye arrangement.

No males were collected. However, it seems to be a new species and I suggest that it be called *Arbanitis marplesi* after Professor B. J. Marples who collected it from Duntroon (near Oamaru).

The nests are found on clay limestone banks and are provided with a trap-door very similar to *Arbanitis gilliesii.*

Among the Mygalids from German Owls there were many spiders from Winchester and Fairlie district. These spiders were smaller than the Palmerston *A. gilliesii* males, with less spines on the maxilla and round the palpal alveolus (Pl. 58, Fig. 56). The smallness of size may be due to poorer feeding, and this may possibly account for less spines on the maxillae and palpal alveolus. Or it may be a separate species or sub-species of *A. gilliesii,* for of the 30 or so examined there was no variation among them. There is a further possibility that these males may belong to *Arbanitis marplesi.*

Arbanitis dendyi (Hogg, 1901).

Maoriana dendyi Hogg, H. R., 1901; P.Z.S. p. 237.
Cantuaria dendyi Hogg, H. R., 1902; P.Z.S.

The genus *Maoriana* was founded by Hogg (1901) and later changed by him to *Cantuaria.* His establishment of a new genus was based on the description of one female sent to him from Christchurch.

As given by Hogg, the following are the essential particulars wherein this spider differs from *Arbanitis*:—

1. The front row of eyes is only slightly procurved.
2. The hind row of eyes is not so recurved.
3. The thoracic fovea is deep and procurved.
4. The lip is broader than long.
5. The posterior sternal sigillae are large, lying half-way between the margin and the central line of the sternum and the others are away from the side margin.

Do any of these points warrant the establishment of a new genus? A rastellum is present, there is a scopula of hair on the metatarsi and tarsi on the first two pairs of legs. There are four spinnerets, six sigillae, and a transverse fovea—all of which surely indicate that this belongs to the genus *Arbanitis* and to this genus it has been transferred.

Female.

Cephalothorax: Very long and broad. Brown, with orangish tinge. Fairly smooth. Fovea straight—slightly procurved.

Abdomen: Fawnish with dark brown speckled pattern.

Chelicera: Rastellum. Eleven teeth on inside of the groove and about eight on outside of it. Thick scopula of orange hair outside this.

Palp: One claw. Scopula on inferior surface of tarsus.

Legs: Patella III and IV have a patch of short spines on anterior surface.

Maxilla: Anterior angle of inferior surface studded with spines and some large setae. (Pl. 55, Fig. 3).

Labium: Broader than long. Convex. Covered with setae.

Sternum: Six sigillae very well marked. Posterior pair pear-shaped and lying half-way between the middle and the margin of the sternum. (Pl. 55, Fig. 3).

Venter: Pattern in dark brown.

Eyes: f.r. procurved. h.r. recurved. f.m.e. hardly their diameter apart x 1 diameter from f.l.e., which are x 1 diameter from h.l.e. The h.m.e. are very small, of pearly lustre and x $\frac{1}{2}$ diameter h.l.e. and about their diameter from the latter (Pl. 56, Fig. 27).

Tarsal claw: One large pectination on each superior claw. (Pl. 57, Fig. 41).

Dimensions: cl. = 8·5 mm. cb. = 6·0 mm. al. = 8·5 mm. ab. = 7·0 mm.

This description differs in some points from that of Hogg. He speaks of a "strongly procurved" fovea. Here this was straight to slightly procurved. The fore median eyes he describes as x $1\frac{1}{2}$ diameter apart, here they were hardly their diameter apart. Nevertheless, it seems we are dealing with the same species, for, as well as

the similarities mentioned, the locality is the same, and would seem to be fairly restricted. Again, considering Hogg's description was taken from only one female, it may not be truly representative.

Male.

This is the first male of the species to be described, and the holotype is to be found in the Otago Museum.

Cephalothorax: Bright orangish. Radiating lines from the fovea very well marked by short setae. Fovea deep and recurved.

Abdomen: Cream, with speckled pattern in dark brown.

Chelicera: Rastellum. Seven large teeth on inside of groove and six small ones on outside near the base. Scopula of brownish hair on outside.

Palp: Bulb with long sharpish point. Alveolus fairly thickly beset with spines, specially on the basal half. No spines on dorsal surface of tarsus or tibia. (Pl. 58, Fig. 57.)

Maxilla: No spines. Scopula of orange hair. (Pl. 55, Fig. 7.)

Labium: Twice as wide as long.

Sternum: Six well-marked bright orange sigillae. (Pl. 55, Fig. 7.)

Eyes: f.r. procurved. h.r. recurved. f.m.e. x $1\frac{1}{2}$ diameter apart x 1 diameter from f.l.e., which are x 1 diameter from h.l.e. The h.m.e. are small and of pearly lustre and practically adjoin the h.l.e.

Dimensions: cl. = 6·0 mm. cb. = 5·0 mm. al. = 6·0 mm. ab. = 4·0 mm.

Legs: i = 22·5 mm. ii = 21·0 mm. iii = 22·0 mm. iv = 27·5 mm. 4123.

The description of the male gives further evidence for the inclusion of the spider in the genus *Arbanitis.*

It is to be noted that this spider differs from *A. marplesi* in that—

1. The cephalothorax is smooth.
2. The dorsal abdominal pattern is different.
3. The sigillal arrangement is different.
4. The venter patterns differ.
5. The eye arrangement is different.

Biology.

The burrow of this spider varies in depth from 4–8 inches, and it is covered by a trap-door. The nest is very similar to that of *A. gilliesii.* An unusual character noticed among these spiders is their non-cannibalistic habits. Some females and a male were kept in one box without any loss of limbs or life. Some kept under a grass sod always huddled together. This shows very different behaviour from any others studied, when to put more than one spider in a jar (without earth to burrow in) meant death to the weaker in a very short while.

Through the habit of taking in food in a liquid state only, spiders are unlikely to have internal parasites. Many, however, are parasitized by mites. These are usually to be found clinging to the cephalothorax and were common on *Arbanitis dendyi.*

Distribution.

A. dendyi has been collected from Christchurch. A German Owl sent from here contained one specimen. It has also been reported by Myers (1927, p. 129) from Wellington.

Genus KORUA nov.

The genus is characterised by the absence of a scopula on the palpal tarsus and on the metatarsus and tarsus of the first two pairs of legs. There are six sternal sigillae. The upper claws are pectinated in a single row. Genotype: *Korua wanganuiensis* n.sp.

Korua wanganuiensis n.sp.

The holotype is in Otago Museum.

Female. (Described from one specimen only.)

Cephalothorax: Brown, fovea recurved.

Abdomen: Light brown with dark speckled pattern.

Chelicera: Rastellum. Seven teeth on inside of cheliceral groove. Five small teeth on outside.

Palp: One terminal claw. No scopula on tarsus but four to five spines on either side of tarsus.

Legs: No scopula on metatarsus or tarsus of legs I and II.

Maxilla: Spines on the anterior angle of the inferior surface. Scopula of orange hair anteriorly. (Pl. 55, Fig. 10).

Labium: No spines.

Sternum: Six sigillae. Posterior pair nearer centre than edge of sternum. (Pl. 55, Fig. 10).

Venter: Light brown speckled with dark brown.

Spinnerets: I. Unsegmented. II. Three segments; short; but these may be partly retracted.

Eyes: f.r. strongly procurved. h.r. recurved. f.m.e. x 1 diameter apart and x $1\frac{1}{2}$ diameter from f.l.e., which are x 2 diameter f.m.e. The h.l.e. x $\frac{3}{4}$ diameter f.l.e. and $\frac{1}{2}$ diameter from these. The h.m.e. of pearly lustre. (Pl. 56, Fig. 30.)

Tarsal claws: Anterior superior claw with two large pectinations; posterior superior claw with one large pectination. (Pl. 57, Fig. 44.)

Dimensions: cl. = 6·0 mm. cb. = 5·0 mm. al. = 10·0 mm. ab. = 6·0 mm.

This differs from *Arbanitis* in the absence of a scopula on the palpal tarsus and on the metatarsus and tarsus of the first two pairs of legs. As this is a character of generic importance (Koch, 1874), this spider represents a new genus of the sub-family Ctenizinae.

One female only has been found in an open burrow in bush at Makirikiri, near Wanganui.

KEY TO THE SPECIES OF THE SUB-FAMILY CTENIZINAE REPRESENTED IN NEW ZEALAND.

1.	Posterior sigillae large, as near the middle as margin of sternum	 2
	Posterior sigillae nearer the margin than middle of sternum	 3
2.	Tarsus of palp, metatarsus and tarsus of legs I and II without scopula	*Korua wanganuiensis*
	Tarsus of palp, metatarsus and tarsus of legs I and II with scopula	*Arbanitis dendyi*
3.	Smooth cephalothorax	 4
	Hairy cephalothorax	 5
4.	Many spines on the maxilla	*Arbanitis huttoni*
	Few spines on the maxilla	*Arbanitis collensis*
5.	Dorsal abdomen and venter patterned . ..	*Arbanitis gilliesii*
	Dorsal abdomen with median dark stripe, no pattern on venter	*Arbanitis marplesi*

Family DIPLURIDAE.

Chelicerae without a rastelum. Lip free. Maxillary lobes wanting. Three claws. Upper claws pectinate in a single or double row. Four or six spinnerets, superior pair long. Thoracic fovea variable.

Sub-family DIPLURINAE (Hogg's *Brachytheleae*).

Upper claws pectinated in a double row. Four spinnerets (Petrunkevitch).

Genus APARUA nov.

Six marginal sigillae. Tarsi without spines. Scopula on all tarsi and on metatarsi I and II. Superior spinnerets not exceeding half the length of the abdomen. Tibia I of the male furnished with an apical spur. Burrower.

Genotype: *Aparua bipectinata* n.sp.

It must be noted here that the burrowing habit of this spider should exclude it from the family Dipluridae, as defined by Petrunkevitch (1928, p. 16); for he states that the whole family are web-weavers. However, the absence of a rastellum and the presence of three tarsal claws bars its acceptance into other families to which it shows any affinity. In external appearance it bears strong resemblance to a Ctenizid, and the double row of tarsal pectinations are not unlike those of *Nemesia* (Pl. 57, Fig. 46). However, in the absence of a rastellum it cannot belong to this group. *Aparua* shows definite affinity to members of Hogg's Brachytheleae, but unfortunately there is no record of the habits of such forms as *Aname*. *Ixamatus*, *Brachythele*. Indeed their habit, seems unknown. The Ctenizid appearance of this Diplurid may be consequential on its burrowing habit.

Aparua bipectinata n.sp.

The holotype is in Otago Museum.

Female.

Cephalothorax: Light brown. Fovea procurved.

Abdomen: Fawn with dark brown pattern.

Chelicera: *No* rastellum. Anterior surface of chelicera armed with bristles. Eight teeth on inside and patch of minute ones near base at outside between last three inner teeth. Scopula of hair outside this.

Palp: One claw. Scopula on inferior surface of tarsus. No spines on tarsus. Claw pectinated in two rows.

Legs: Scopula of hair on metatarsus and tarsus of legs I and II. Slight scopula on tarsus of legs III and IV.

Maxilla: Anterior angle of inferior surface covered with short stout spines. Thinnish scopula of orange hair, some anteriorly. (Pl. 55, Fig. 9.)

Labium: Usually two to three short spines on anterior border of this. Some long setae. (Pl. 55, Fig. 9.)

Sternum: Six sigillae right on edge of sternum. Posterior pair making a dent.

Venter: Pattern in dark brown.

Spinnerets: I. Unsegmented and very small. II. Three long segments—as long as half the total length of the abdomen. The last segment slightly longer than the middle one and tapering to a point.

Eyes: f.r. straight. h.r. recurved. f.m.e. barely their diameter apart x $\frac{1}{2}$ diameter from f.l.e. which are the largest and about x $1\frac{1}{2}$ f.m.e. The h.l.e. practically adjoining f.l.e. and in like relation to the h.m.e. which are large and opalescent (Pl. 56, Fig. 33).

Tarsal claw: Double row of pectinations on superior claws. Small rudimentary inferior claw. (Pl. 57, Fig. 45, 45a.)

Dimensions: cl. = 5·0 mm. cb. = 4·0 mm. al. = 6·5 mm. ab. = 3·5 mm.

Male. (Described from one specimen.)

Cephalothorax: Brown. Fovea straight-procurved. Setae round edge of cephalothorax well marked.

Abdomen: Fawnish with dark brown chevron pattern.

Chelicera: No rastellum. Eight teeth on inside of groove. Some very small teeth at base on outside. Scopula of hair outside these.

Palp: Palpal organ consists of twisted bulb with very blunt point. There is no marked alveolus. No spines on tarsal or tibial joint. (Pl. 58, Fig. 58.)

Leg I: Tibia bearing large spine distally on inferior external surface. (Pl. 58, Fig. 65.)

Maxilla: Spines on anterior angle of inferior surface. Orange scopula along anterior border. (Pl. 55, Fig. 13.).

Labium: Rectangular. Setae. One small spine.

Sternum: Similar to female. Six sigillae. First two pairs near edge of sternum and the third pair right on the edge, making a dent in sternum. (Pl. 55, Fig. 13.)

Venter: Pattern in dark brown similar to the female.

Eyes: f.r. straight. h.r. recurved. The f.m.e. just diameter apart x $\frac{1}{2}$ diameter from f.l.e., which are the largest eyes and about x $1\frac{1}{2}$ f.m.e. The h.l.e. x $\frac{3}{4}$ f.l.e. practically adjoining these and in like relation to the h.m.e., which are quite large and opalescent.

Tarsal claws: Three. Superior claws pectinated in a double row.

Dimensions: cl. = 4·0 mm. cb. = 3·0 mm. al. = 4·0 mm. ab. = 2·5 mm.

Biology.

The spider builds an open burrow without a trap-door. It is found on the bush floor or on banks just out of the bush. The burrow is lined with silk, it is unbranched and may be up to 6–7 inches in depth. It is similar in general appearance to an *Arbanitis huttoni* burrow. The generic name is a Maori word meaning " hole ".

Distribution.

Spiders were collected from bush at Makirikiri, near Wanganui. One female sent from Auckland seems to be the same though larger.

Sub-family MACROTHELINAE.

Sternum normal. Upper claws pectinated in a single row. Four spinnerets. Web-weavers.

Genus PORRHOTHELE Simon, 1892.

Characteristic of the genus is the large size of the spiders. There are six sigillae. The tarsi of all the legs are without spines. In the male the tibia of the first leg has a swelling and the tarsus shape is characteristic. (Pl. 58, Fig. 67.)

Porrhothele antipodiana (Walckenaer, 1837).

Mygale antipodiana Walckenaer, 1837. Ins. Apt., 1, p. 230.
Mygale quoyi Lucas, 1846. d'Orbigny, Dict. d'Hist. 8, p. 503.
Cteniza hexops and *C. antipodum* White, 1849. P.Z.S., p. 3.
Hexops whitei Aus., 1871. Verh. Ges. Wien., p. 155.
Macrothele insignipes Simon, 1891. Ann. Soc. Ent. Fr., 60, p. 308.
Porrothele antipodiana Simon, 1892. Histoire Naturelle des Araignées, 1, p. 185.
Arbanitis kirkii Urquhart, 1893. T.N.Z.I. xxvi, p. 204.
Porrhothele antipodiana Simon. Hogg, H. R., 1901. P.Z.S., p. 266.
Porrhothele simoni Hogg, 1901. P.Z.S., p. 269.

A neotype of this species has been established and placed in the Otago Museum.

Female.

Cephalothorax: Bright orange ochreous. Fovea deep, circular, procurved (anterior curve). In front of the clypeus there is a triangular chitinised portion which can usually be seen from the dorsal surface.

Abdomen: No very marked pattern.

Chelicera: Fangs black-red. Ten irregular large black teeth on inside of furrow. Opposite the sixth there are two irregular rows of small, transparent teeth on the outside. Fine scopula on outside of this.

Palp: One claw. Fine scopula on tarsus.

Maxilla: Very thickly studded with spines. Orange scopula anteriorly. (Pl. 55, Fig. 17.)

Labium: Very thickly studded with spines.

Sternum: Six sigillae. (Pl. 55, Fig. 17.)

Venter: Dark brown. Lung books and genital operculum made conspicuous by yellow outlines.

Spinnerets: I. Unsegmented. II. Three segments with length of 9·0 mm.

Eyes: f.r. straight. h.r. recurved. f.m.e. just their diameter apart x¾–x1 diameter from f.l.e., which are the largest eyes. The h.l.e. are same diameter as f.m.e. (x¾ f.l.e.) and this distance from f.l.e. H.m.e. of pearly lustre x½ diameter h.l.e. (Pl. 56, Fig. 31.)

Tarsal claw: Seven pectinations running in a crosswise row on superior claws. (Pl. 57, Fig. 52.)

Dimensions: Some mature female measurements in millimetres:—
cl. = 11·0, 10·0, 10·0, 8·0, 7·5. cb. = 7·5, 9·0, 9·0, 7·0, 6·0.
al. = 14·0, 14·5, 12·8, 13·0, 10·5. ab. = 10·5, 10·5, 8·0, 9·5, 7·0.

Male.

Cephalothorax: Bright orange yellow. Fovea very deep, circular.

Abdomen: Patterned. Very bristly.

Chelicera: Ten teeth on inside of the groove. One or two irregular rows of smaller light brown teeth on outside at base.

Palp: No real alveolus, but furrow with hairs on either side. Bulb drawn out to a very fine point. Ten stout black bristles on tip of radial joint of tarsus. (Pl. 58, Fig. 61.)

Leg. I: Tibia with spined swelling. (Pl. 58, Fig. 67.)

Maxilla: Studded with small spines. (Pl. 55, Fig. 21.)

Labium: Studded with small spines.

Sternum: Six sigillae. (Pl. 55, Fig. 21.)

Spinnerets: I. Unsegmented. II. 6·5 mm. long.

Eyes· f.r. straight. h.r. recurved. f.m.e. x $\frac{3}{4}$ diameter apart and this distance from f.l.e., which are the largest. H.l.e. x 1 f.m.e. and this distance from f.l.e. The h.m.e. of pearly lustre x $\frac{1}{2}$ f.l.e. and x $\frac{1}{2}$ their diameter from h.l.e.

Hogg (*loc. cit.*) established a species *Porrhothele simoni* based on the following differences from *P. antipodiana*:—

1. The distance apart of the fore median eyes.
2. The colour of the thorax.
3. The curvature of the fovea.

His observations were made on two females sent to him from Christchurch.

Now, since the space between the eyes may vary slightly with age (de Dalmas, 1917) and the colour is also variable to some degree, usually being lighter in the younger spiders, two of these differences may be ignored. Further, it is a matter of opinion when dealing with a deepish circular fovea whether the anterior or posterior curve is the one regarded, and the curve will be recurved or procurved accordingly. From the drawing accompanying Hogg's description *P. simoni* would seem to have a fairly deep circular fovea. The validity of this species is very doubtful, and will remain so unless a male showing definite differences from *P. antipodiana* is found; until then it may be regarded as synonymous with *P. antipodiana*.

An examination of the type specimen of *Arbanitis kirkii* Urquhart, kindly sent down by the Canterbury Museum, showed that this belongs to the genus *Porrhothele* and is synonymous with *P. antipodiana*.

Biology.

Porrhothele spins a tubular web under stones, logs, or the loose bark of trees. It may sometimes burrow into the earth to make a kind of main chamber to the nest. It is in this chamber that the cocoons are found, and the moulted skins of the spider are sometimes found here. Radiating threads usually extend out from the opening of the tube, which may be double. The length of the tube varies from 6–10 inches. The webs are constructed in a very short time, for in less than an hour a spider in a jar had spun quite an elaborate branching tube. The whole abdomen sways from side to side as the long spinnerets pay out their thick silk strands. The male spiders are found in similar nests to the females under stones, or bark or in crevices.

Food debris is found in the nest usually woven into the lining of the tube. The number of ecdyses gone through before the spiders reach maturity is not known. The spiders do moult, however, after they have reached maturity. Females with young have been found to do so, and the moulted skins of males complete with palpal organs have been collected. Times of moulting seem to be controlled mainly or entirely by food factors.

Dead male *Porrhothele* were found in nests in a peculiar fungal condition, being covered with a yellowish white fur. No explanation of this condition is offered. The male spider is about the same size as the female, with a somewhat smaller abdomen.

It seems very likely that the bumps and processes on the tibiae of the first leg in the males play an important part during the copulation of these spiders. Any two spiders of the same species coming face to face rear up raising their palps and the first two pairs of legs into the air, and the fangs are raised into a striking position. It is presumed that in courtship the male spider moves deftly and grasps the female with his first pair of legs, so that her fangs are held open, wedged between the groove on the tarsus and the bump on the tibia, which close on each other to form an effective clamp. Thus free from the menace of the female's fangs the male is ready to copulate.

Eggs of *Porrhothele* were collected and allowed to develop. The cocoon contains an enormous number of eggs; the contents of one cocoon totalled 241. These eggs are quite loosely packed together in the cocoon, which consists of two thin layers of silk. Eggs collected early in December developed, and the spiderlings hatched approximately 30 days after laying. The spiderlings moulted after a few days. During the first instar period, the spiders are fairly inactive and lie on their backs stretching the limbs. These spiders moulted after about five weeks, and the second instar spiders are very active and hairy. They spin small web-tubes and begin to feed.

Distribution.

Porrhothele antipodiana has the widest distribution known among the Mygalids of New Zealand. In the vicinity of Dunedin it has been collected from Long Beach, Portobello, Quarantine Island, and from Akatore. In the North Island it is known from Wellington, Masterton and Wanganui.

Porrhothele huttoni (Cambridge, 1873).

Macrothele huttoni Cambridge, 1873. T.N.Z.I. vi, p. 200.

Porrhothele antipodiana Hogg, H. R., 1901. P.Z.S., p. 267.

Hogg (*loc. cit.*) considers *P. huttoni* synonymous with *P. antipodiana*. He does not appear quite justified in doing this, for, from Cambridge's description (*loc. cit.*) and from an examination of his accompanying plates there is no mention or drawing made of spines on the maxillae and labium. If this is really so, it would differ from the *P. antipodiana* male, and so surely constitute a new species. The fact that this was not remarked on is extraordinary; however, in the meantime, it is best left as a distinct species.

Porrhothele avocae n.sp.

The holotype is placed in the Otago Museum.

Female.

Cephalothorax: Constant pale yellowish brown. Fovea deep, circular, recurved (anterior curve). In front of the clypeus there is a small triangular chitinised portion which cannot generally be seen from the dorsal surface.

Abdomen: Greyish with long setae.

Chelicera: Ten irregular teeth on inside. Smaller ones in two irregular rows at the base.

Palp: One claw. Few setae.

Maxilla: Spinose. (Pl. 55, Fig. 18.)

Labium: Spined.

Sternum: Six sigillae. (Pl. 55, Fig. 18.)

Venter: Grey. Fairly smooth with fine hairs, yellowish brown over the lung books and genital operculum.

Spinnerets: I. Unsegmented. II. Three segments, 6·0 mm. long.

Eyes: f.r. straight, slightly procurved. h.r. recurved. f.m.e. just less than their diameter apart and x ½ diameter from f.l.e., which are the largest eyes. The h.l.e. x ½ diameter of f.l.e. and x ½ this from f.l.e. The h.m.e. pearly lustre, triangular shape x ¾ h.l.e. (Pl. 56, Fig. 32.)

Tarsal claw: Nine to ten pectinations in crosswise row on superior claws (Pl. 57, Fig. 53.)

Dimensions: Mature females: cl. = 8·0 mm., 5·5 mm. cb. = 6·0 mm., 4·0 mm. al. = 8·5 mm., 8·0 mm. ab. = 6·0 mm., 6·0 mm.

Male. (From one specimen only.)

This had just moulted, so was pale yellowish and soft.

Fovea: Circular, deep, recurved.

Abdomen: Dark grey-black. No pattern. Long, fine setae on dorsal surface.

Chelicera: Eleven teeth on inside of furrow. Some smaller ones on outside near base.

Palp: Very simple. As in *P. antipodiana.* No marked alveolus.

Maxilla: Anterior angle with spines. Orange scopula anteriorly and a tuft of brown hair near the trochanterial end of the maxilla. (Pl. 55, Fig. 22.)

Labium: Spines and setae.

Sternum: Six large sigillae. (Pl. 55, Fig. 22.)

Spinnerets: I. unsegmented. II. Three segments 6·0 mm. long.

Eyes: f.r. slightly recurved. h.r. recurved. f.m.e. their diameter apart and x ½ diameter from f.l.e. These are about x 1½ h.l.e. and x ½ diameter from them. H.m.e. solid U-shape open behind, where pigment is not yet present.

Dimensions: cl. = 8·0 mm. cb. = 7·0 mm. al. = 10·0 mm. ab. = 7·5 mm.

Biology.

The spider builds tubes similar to *P. antipodiana,* and has been collected, so far, only at Avoca (Mid-Canterbury, in Arthur's Pass region). The altitude here is 3,662 feet.

KEY TO NEW ZEALAND SPECIES OF THE SUB-FAMILY MACROTHELINAE.

1. Spines on maxilla and labium of male 2
   No spines on maxilla and labium of male .. .. *P. huttoni*
2. Fore-median eyes diameter apart. Cephalothorax bright orange ochreous (but may vary). Size ranging up to 20.0 mm. in length. Male about 13.0 mm. in length. Abdomen dark-brown speckled pattern. Width 4.5 mm. Seven pectinations on superior tarsal claw. .. *P. antipodiana*
   Fore-median eyes less than diameter apart. Cephalothorax yellowish brown. Size 14.5 mm. Male (18.0 mm.) larger than female. Abdomen dark grey black. Width 7.5 mm. Nine to ten pectinations on superior tarsal claw. .. .. *P. avocae*

Sub-family HEXATHELINAE.

Upper claws pectinated in a single row. Six spinnerets. Eyes in a compact group. Thoracic groove transverse. Sigillae present.

Genus HEXATHELE Ausserer, 1871.

Hexathele hochstetteri Ausserer, 1871.

Hexathele hochstetteri Ausserer, 1871. Verh. Ges. Wien, xxi, p. 172.
Hexathele hochstetteri, Koch, L., 1873. Arach. Aus. i, p. 459. Hogg, H. R., 1901. P.Z.S. p. 276.
Hexathele petriei Goyen, 1886. T.N.Z.I. xix, p. 207. Hogg, H. R., 1901. P.Z.S., p. 278.
Hexathele huttoni Hogg, H. R., 1908. P.Z.S., p. 337.
Hexathele websteri Hogg, H. R., 1908. *loc. cit.* supra.
Hexathele hochstetteri, de Dalmas, 1917. Ann. Soc. Ent. Fr.

Female.

Cephalothorax: Yellowish-brown or orange colour. Fovea short, straight.

Abdomen: Dark patterned with five dorsal pairs of white spots.

Chelicera: Fifteen large irregular teeth on inside. Few minute ones on outside at the bottom.

Palp: One claw. Many spines on tarsus and metatarsus.

Maxilla: Fairly spinose from anterior angle extending over about half the surface. (Pl. 55, Fig. 19.)

Labium: Spines on anterior half.

Sternum: Squarish. Six sigillae. (Pl. 55, Fig. 19.)

Eyes: f.r. procurved. h.r. strongly recurved. f.m.e. just less than their diameter apart x $\frac{3}{4}$ diameter from f.l.e., which are the largest (x 2 f.m.e.). The h.l.e. x $\frac{3}{4}$ f.l.e. and h.m.e. about x $1\frac{1}{2}$ f.m.e. (Pl. 56, Fig. 34.)

Tarsal claw: Eight-nine pectinations in crosswise row on superior tarsal claw. (Pl. 57, Fig. 47.)

Dimensions: cl. = 7·0 mm. cb. = 6·0 mm. al. = 10·0 mm. ab. = 7·0 mm.

Male.

Cephalothorax: Dark reddish brown. Fovea short, straight.

Abdomen: As in female. Dark, with light spots.

Chelicera: Ten teeth in row on inside, none on outside.

Palp: Bulb drawn out into a fine, sharp point; simple kind of alveolus. (Pl. 58, Fig. 62.)

Tibia and Tarsus of Leg I: Spined swelling on tibia, excavation of tarsus. (Pl. 58, Fig. 68.)

Maxilla: Spines on anterior angle. (Pl. 55, Fig. 23.)

Labium: Spines on anterior half.

Sternum: Like female. Six sigillae. (Pl. 55, Fig. 23.)

Venter: Six spinnerets.

Eyes: f.r. procurved. h.r. recurved. f.m.e. x $\frac{1}{2}$ diameter apart and about this distance from larger (x 2 f.m.e.) f.l.e. The h.l.e. x $\frac{3}{4}$ f.l.e. and same distance from this as these are from f.m.e. The h.m.e. x 1 f.m.e. and about x $\frac{1}{2}$ from f.m.e.

Dimensions: cl. = 7·0 mm. cb. = 6·5 mm. al. = 8·0 mm. ab. = 4·5 mm.

This description of the male fits in with Goyen's description of *Hexathele petriei*, which is here synonymized with *H. hochstetteri*. The colour difference (Goyen *loc. cit.*) may be due to climate. It is often noticed that further south animals tend to become darker due to increase in pigment. de Dalmas (*op. cit.*) also classes *H. petriei* as well as Hogg's *H. huttoni* and *H. websteri* as synonymous with *H. hochstetteri.*

Biology.

These spiders are large and resemble *Porrhothele* not only in build but in habit. They construct tough tubular webs under stones, in banks or under the loose bark of trees.

Distribution.

Hexathele hochstetteri has been reported from both the North and South Islands.

Hexathele sandersoni n.sp.

The holotype is placed in the Otago Museum and paratypes will be sent to other Museums if requested.

Female.

Cephalothorax: Lightish brown—*not* yellow. Fovea circular and recurved, with well marked radiating lines out from it. The rear of the prosoma is markedly bilobed in shape.

Abdomen: Very marked pattern. Dark dorsal knotted median pigmented band with lateral branches down sides.

Chelicera: Twelve large teeth on inside. Some very minute ones on outside opposite the last five internal ones.

Palp: One claw with ten pectinations.

Maxilla: Spinose. (Pl. 55, Fig. 20.)

Labium: Anterior half spined.

Sternum: Six sigillae. (Pl. 55, Fig. 20.)

Eyes: f.r. straight—slightly procurved. h.r. recurved. f.m.e. less than their diameter apart and same distance from f.l.e., which are x $1\frac{1}{2}$ diameter of f.m.e. The h.l.e. x 1 f.l.e. and x $\frac{1}{4}$ diameter from f.l.e. The h.m.e. of pearly lustre, triangular shape x $\frac{1}{2}$ h.l.e. (Pl. 56, Fig. 35.)

Tarsal claw: Eight pectinations in crosswise row on superior claw. Inferior claw with two small pectinations. (Pl. 57, Fig. 48.)

Dimensions: cl. = 6·5 mm. cb = 5·0 mm. al. = 9·0 mm. ab. = 6:0 mm.

Male.

Cephalothorax: Yellowish brown. Fovea deep, recurved. Radiating lines from fovea well marked.

Abdomen: Very characteristic pattern. Dark knotted median band with regular lateral branches down the sides.

Chelicera: Twelve to fourteen irregular teeth on inside of groove. None on outside. Fine scopula of hair on outside.

Palp: Bulb drawn out into fine sharp point. Simple alveolus. (Pl. 58, Fig. 63.)

Tibia of Leg I: Distal swelling.

Maxilla: Spines on anterior angle. (Pl. 55, Fig. 24.)

Labium: Spines on anterior half, not thickly studded.

Sternum: Six sigillae. (Pl. 55, Fig. 24.)

Eyes: f.r. procurved. h.r. recurved. f.m.e. hardly their diameter apart and about x $\frac{1}{2}$ diameter from f.l.e. They are x 2 f.m.e. The h.l.e. x $\frac{7}{8}$ f.m.e. The h.m.e. are triangular in shape adjoining the h.l.e. and x 1 f.m.e.

Dimensions: cl. = 6·0 mm. cb. = 5·5 mm. al. = 6·5 mm. ab. = 4·5 mm.

This species differs from *H. hochstetteri* in the distinctive abdominal pattern, the curvature of the thoracic fovea, the pectination of the inferior tarsal claw in *H. sandersoni.* The specific name is after Mr. W. Sanderson, who sent these spiders from North Auckland.

Biology.

As in *H. hochstetteri* the web tube may be found under stones, in banks, or under the bark of trees. Radiating threads from the opening are usually present, and these though primarily to keep the large tube open, may serve to trap food.

A *Hexathele sandersoni* sent from Auckland on the 19th July was kept in a match-box with a little dry grass till the 9th August. It was then weighed before it was given some water. After drinking this it was again weighed, and it showed a 22% increase on the first weight. The actual increase in weight was 0·13 grams. This phenomenal percentage increase is in keeping with the large gut volume of the spider. The diverse branchings of the alimentary canal also makes fasting for long periods possible.

The heart beats could be observed clearly through the skin on the anterior dorsal part of the abdomen. Counts taken of *Hexathele* show variation with degree of excitement. The average number of beats per minute was 40, increasing to 80 when the spider was excited.

Hexathele sandersoni laid eggs in a cocoon on September 28th, 1942. There were 31 large eggs, with diameter of 1·75 mm. The cocoon was placed just below the exit attached to the side of the tube. The cocoon consisted of only one silk layer. This is an earlier date for cocoons than in the other Mygalids and may perhaps be accounted for by the milder northern climate. The eggs developed at about the same rate as *Porrhothele.*

Distribution.

H. sandersoni appears to be fairly widespread in the Auckland locality. Those sent were collected from Mata (N. Auckland) and from the Auckland Harbour region.

KEY TO NEW ZEALAND MEMBERS OF THE SUB-FAMILY HEXATHELINAE.

1. Fovea short, straight. Abdomen dark patterned with five pairs of white spots. Fifteen large teeth in cheliceral groove. Inferior tarsal claw without pectination .. .. *Hexathele hochstetteri*
2. Fovea deep, recurved. Very characteristic abdominal pattern. Dark median knotted band with lateral branches extending down the sides. Twelve large teeth in cheliceral groove. Inferior tarsal claw with two small pectinations. .. .. .. *Hexathele sandersoni*

Family MIGIDAE.

Chelicerae without a rastellum. Three claws. Upper claws with one or several teeth sometimes dissimilar. Maxillary lobes wanting. Four spinnerets. Thoracic groove transverse. Sternum normal. With sigillae. Eight eyes in two rows. (Petrunkevitch, 1928.)

Sub-family MIGINAE.

Thoracic groove simple. Third tibia normal. Head not elevated over thorax.

Genus MIGAS Koch, 1873.

The thoracic fovea is recurved, the chelicerae are geniculate, characteristically there is a row of spines along either side of the tarsus and metatarsus of the first two pairs of legs. There are two sigillae on the sternum.

Migas paradoxus Koch, 1873.

Migas paradoxus Koch, L., 1873. Arach. Aus., p. 467. Hogg, H. R., 1901. P.Z.S., p. 229. de Dalmas, 1917. Ann. Soc. Ent. Fr.

The type specimen of this species, the genotype, is in Vienna.

Female.

Cephalothorax: Brown. Fovea recurved.

Abdomen: Darker brown, with five pairs of lighter spots on the dorsal surface.

Chelicera: Geniculate. No rastellum. Three to four large spines on inside of cheliceral groove. Four smaller ones on outside.

Maxilla: Few scattered spines on anterior angle. Brownish-orange scopula anteriorly. (Pl. 55, Fig. 14.)

Labium: Rectangular in shape. Spines anteriorly.

Sternum: Triangular in shape. Two posterior sigillae. (Pl. 55, Fig. 14.)

Venter: Pale brown.

Eyes: f.r. slightly recurved. h.r. strongly recurved. f.m.e. x ½ diameter apart. x 1 diameter from f.l.e. The h.l.e. x ½ diameter of f.l.e. and about x 1 diameter from f.l.e. The h.m.e. of pearly lustre. (Pl. 56, Fig. 36.)

Tarsal claw: Three pectinations on superior claws. (Pl. 57, Fig. 49.)

Dimensions: cl. = 5·0 mm. cb. = 4·0 mm. al. = 7·0 mm. ab. = 4·5 mm.

Referring to *M. paradoxus,* Hogg (*loc. cit.*) says that there is a remarkable double row of spines on metatarsus IV. Surely this is a mistranslation, for Koch says: "die beiden hinterpaare mit ausnahme eines dunnen stachels am ende der metatarsen unbewehrt." Both the posterior pairs are unarmed with the exception of a thin spine at the end of the metatarsus.

Biology.

M. paradoxus has a burrow with trap-door either in the ground or on trees.

Distribution.

Specimens were sent from Auckland, Wellington (Wilton's Bush) and New Plymouth.

Migas distinctus Cambridge, 1879.

Migas distinctus Cambridge, O. P., 1879. P.Z.S., p. 683. Goyen, P., 1886. T.N.Z.I. xix, p. 210.
Migas sandageri Goyen, 1890. T.N.Z.I. xxiii, p. 123.
Migas distinctus Hogg, H. R., 1901. P.Z.S., p. 229.
Migas sandageri Hogg, H. R., 1901. P.Z.S., p. 229.

Female.

Cephalothorax: Light to darkish brown.

Abdomen: Dark grey-black with five pairs of lighter spots on dorsal surface.

Chelicera: Three large teeth on inside of groove. Four on outside.

Palp: One claw with a large pectination. Tarsus and metatarsus bespined laterally.

Maxilla: Spines on anterior half of inferior surface. (Pl. 55, Fig. 11.).

Labium: Studded with thick black spines.

Sternum: Two sigillae. (Pl. 55, Fig. 11.)

Venter: Pale brown.

Eyes: f.r. straight. h.r. recurved. f.m.e. their diameter apart and same distance from f.l.e. The h.l.e. x ¾ diameter from f.l.e. The h.m.e. of pearly lustre x ½ diameter from h.l.e. (Pl. 56, Fig. 37.)

Tarsal claw: Two to three sharp pectinations on superior claw. (Pl. 57, Fig. 50.)

Dimensions: Average length of the spider is 9·0 mm.

Male.

Cephalothorax: Bright pinkish orange. Dark brown round the ocular region. Setae round edge. Fovea recurved.

Abdomen: Small, dark brown, with traces of pattern like female.

Chelicera: Three large teeth on inside of groove. Four small ones on outside.

Palp: Bulb tapering to curved pointed tip. No marked alveolus. (Pl. 58, Fig. 59.)

Legs: 4123. No marked row of spines on tarsus and metatarsus I and II as in the females. Process on tibia I. (Pl. 58, Fig. 66.)

Maxilla: No spines, orange scopula anteriorly. (Pl. 55, Fig. 15.)

Labium: No spines. Covered with setáe.

Sternum: Two sigillae covered with setae. (Pl. 55, Fig. 15.)

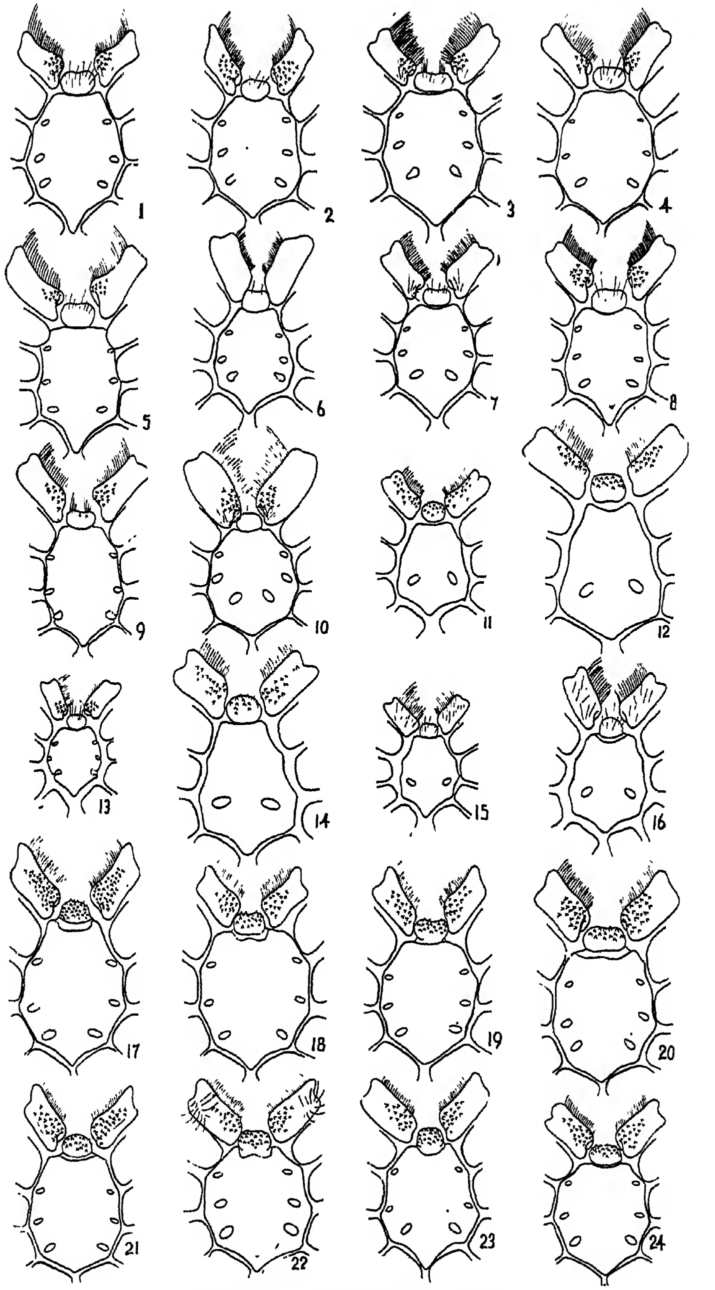
Venter: Dark brown. Lung books and genital operculum lighter.

Eyes: f.r. recurved. h.r. recurved. f.m.e. x 1 diameter apart and x 1 diameter from f.l.e. The h.l.e. x 1 diameter from f.l.e. The h.m.e. of pearly lustre x ½ diameter from h.l.e.

Dimensions: cl. = 3·0 mm. cb. = 3·0 mm. al. = 3·5 mm. ab. = 2·0 mm.

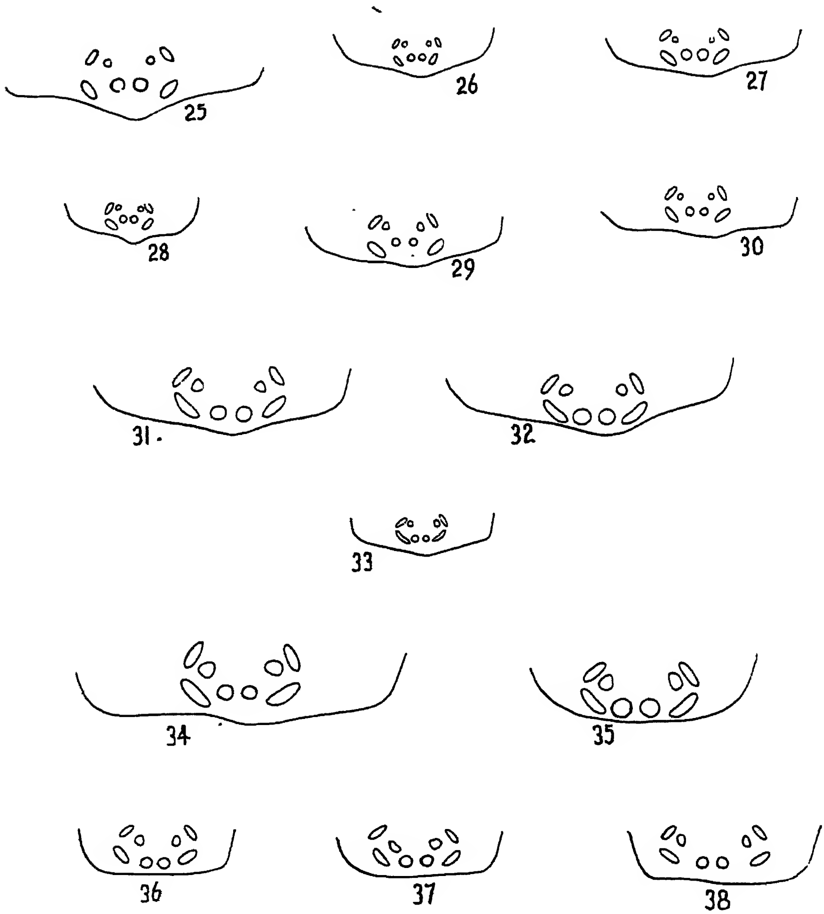
Hogg (*loc. cit.*) in his key to the *Migas* species distinguishes *M. sandageri* from *M. distinctus* by the absence of spines on the maxillae and labium of the latter. Spines are absent only in the male spider. The female (Cambridge *loc. cit.*) has a spinose labium and maxilla as described above. The elimination of this supposed difference makes *M. sandergeri* synonymous with *M. distinctus*. The habit of building the nest on the bark of a tree (Goyen *loc. cit.*) is of no specific importance as *M. distinctus* also sometimes does this. *M. distinctus* may be distinguished from *M. paradoxus* by its smaller size, difference in abdominal colour and markings, the hexagonal shape of the sternum (cf. *M. paradoxus* is triangular). There are more spines on the labium. The front row of eyes is straight and the fore median eyes are their diameter apart (cf. *M. paradoxus*, front row of eyes are slightly recurved and the fore median eyes are half their diameter apart).

de Dasmas (*op. cit.*) also doubted the validity of *M. sandageri*, and he placed it as synonymous with *M. paradoxus*. de Dalmas



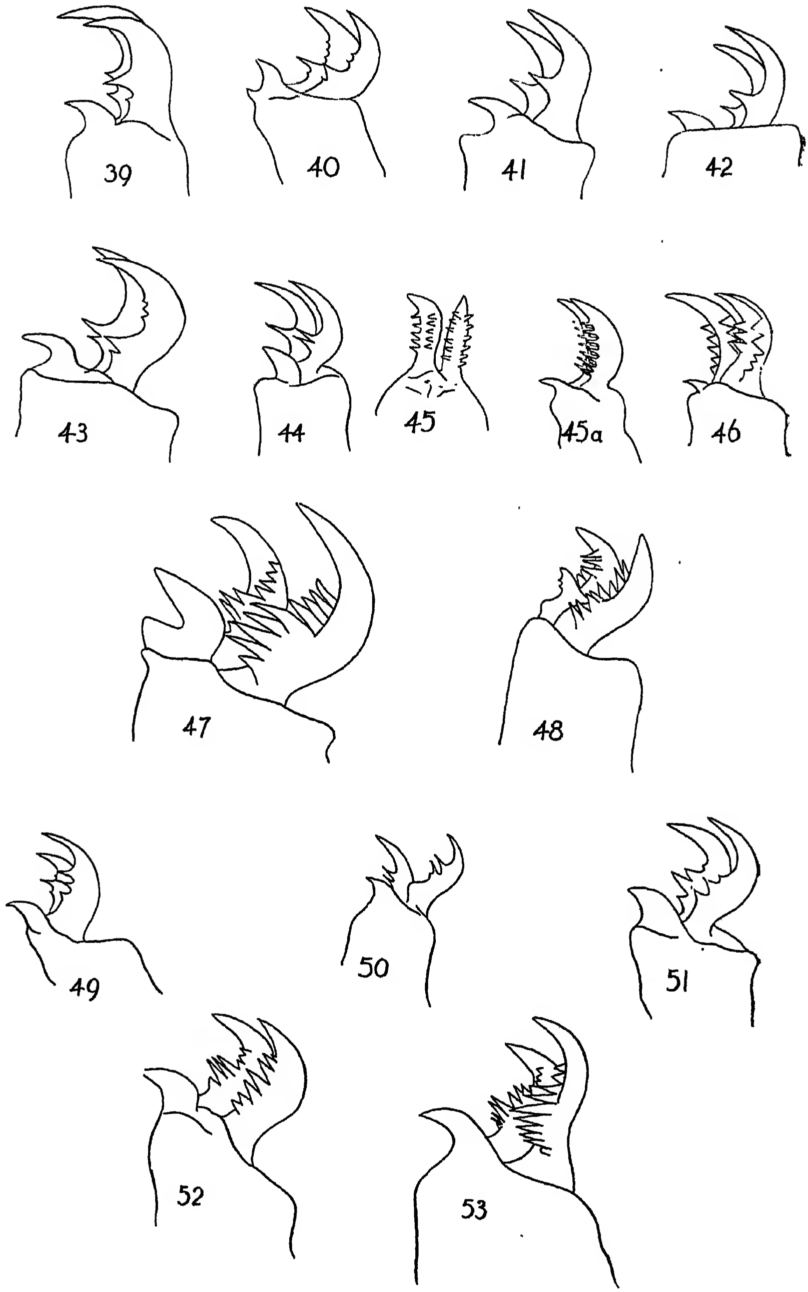
STERNUM, MAXILLAE AND LABIUM.

FIG. 1—*A. gilliesii* female.
FIG. 2—*A. huttoni* female.
FIG. 3—*A. dendyi* female.
FIG. 4—*A. collensis* female.
FIG. 5—*A. gilliesii* male.
FIG. 6—*A. huttoni* male.
FIG. 7—*A. dendyi* male.
FIG. 8—*A. marplesi* female.
FIG. 9—*Aparua bipectinata* female.
FIG. 10—*K. wanganuiensis* female
FIG. 11—*M. distinctus* female.
FIG. 12—*M. taierii* female.
FIG. 13—*Aparua bipectinata* male
FIG. 14—*M. paradoxus* female.
FIG. 15—*M. distinctus* male.
FIG. 16—*M. taierii* male.
FIG. 17—*P. antipodiana* female
FIG. 18—*P. avocae* female.
FIG. 19—*H. hochstetteri* female
FIG. 20—*H. sandersoni* female.
FIG. 21—*P. antipodiana* male.
FIG. 22—*P. avocae* male.
FIG. 23—*H. hochstetteri* male.
FIG. 24—*H. sandersoni* male.



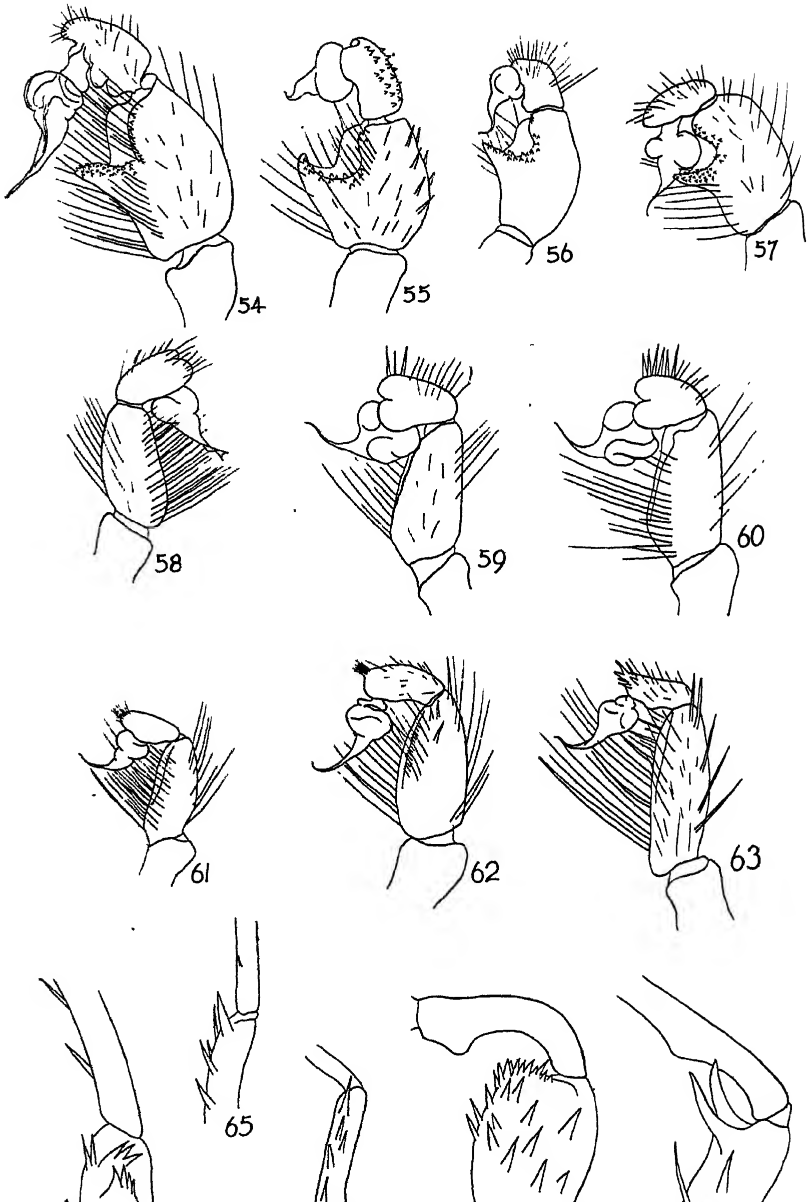
EYES × 2½

FIG. 25—*A. gilliesii.*
FIG. 26—*A. huttoni.*
FIG. 27—*A. dendyi.*
FIG. 28—*A. collensis.*
FIG. 29—*A. marplesi.*
FIG. 30—*K. wanganuiensis.*
FIG. 31—*P. antipodiana.*
FIG. 32—*P. avocae.*
FIG. 33—*Aparua bipectinata.*
FIG. 34—*H. hochstetteri.*
FIG. 35—*H. sandersoni.*
FIG. 36—*M. paradoxus.*
FIG. 37—*M. distinctus.*
FIG. 38—*M. taierii.*



TARSAL CLAWS × $7\frac{1}{2}$

FIG. 39—*A. gilliesii.*
FIG. 40—*A. huttoni.*
FIG. 41—*A. dendyi.*
FIG. 42—*A. marplesi.*
FIG. 43—*A. collensis.*
FIG. 44—*K. wanganuiensis.*
FIG. 45, 45a—*Aparua bipectinata.*
FIG. 46—*Nemesia sp.*
FIG. 47—*H. hochstetteri.*
FIG. 48—*H. sandersoni.*
FIG. 49—*M. paradoxus.*
FIG. 50—*M. distinctus.*
FIG. 51—*M. taierii.*
FIG. 52—*P. antipodiana.*
FIG. 53—*P. avocae.*



PALPAL ORGANS OF MALE.

FIG. 54—*A. gilliesii.* × 3.
FIG. 55—*A. huttoni.* × 3.
FIG. 56—*Arbanitis sp.* from Winchester. × 3.
FIG. 57—*A. dendyi.* × 3.
FIG. 58—*Aparua bipectinata.* × 5
FIG. 59—*M. distinctus.* × 5.
FIG. 60—*M. taierii.* × 5.
FIG. 61—*P. antipodiana.* × 3.
FIG. 62—*H. hochstetteri.* × 3.
FIG. 63—*H. sandersoni.* × 3.

TIBIA OF 1st LEG OF MALE. × 3.

FIG. 64—*A. gilliesii.*
FIG. 65—*Aparua bipectinata.*
FIG. 66—*M. distinctus.*
FIG. 67—*P. antipodiana.*
FIG. 68—*H. hochstetteri.*

separated the species into those that lived on trees *M. paradoxus*, and those that burrowed in the ground *M. distinctus*. The fact that *M. sandageri* was found on trees caused him to place it with *M. paradoxus*. However, *M. distinctus* also makes nests on trees and from Goyen's description *M. sandageri* appears synonymous with *M. distinctus*.

Biology.

The Miginae all possess unbranched trap-door nests. *Migas distinctus* nests have been found in the ground, under stones or on trees. In every case they have been coastal, and instances of spiders in the three places may be found within a hundred yards of one another at Long Beach (Dunedin). When found on cliffs or banks by the sea, the burrow is usually about two and a-half inches deep and the trap-door seldom exceeds ¼ inch in diameter. On trees the nests are shorter, from an inch to an inch and a half. They were found in elderberry and kowhai trees: in the latter case they were restricted to the basal two feet of the tree, but on the elderberry they were found as high up as eight feet from the ground. The door is generally at the end, but specimens have been found where it may be central, or there may be a door at either end of the nest. The nests found under stones were shorter still, about ½ inch to 1½ inches in length. *Migas* has no rastellum on the chelicerae, but on either side of the metatarsus and tarsus of the palp and first two pairs of legs there is a row of strong setae which are used in digging the burrow. Several young *Migas distinctus* 2·5 mm. long were observed under the binoculars, making their first nest. The spider turns about a few times making a slight hollow before the process of digging begins.

During the excavation the fangs carry up grains of earth which are flicked away from the burrow by the pedipalps sometimes to a distance of an inch from the mouth of the tube. This process continues until the depth of the burrow well exceeds the length of the spider. The spinnerets move back and forth lining the tube with silk as this is excavated, and when deep enough the spider builds up a little wall round the mouth of the tube. To do this it brings up from the bottom of the burrow pellets of earth which are put into place with the aid of the pedipalps. When the wall is complete and it has been further strengthened by a layer of silk the spider appears to rest for a while before beginning the construction of the door, which is begun from the hinge. From the bottom or sides of the hole the spider collects earth which is pressed into a flat, roughly rounded pellet and carried up in the fangs. Possibly some form of secretion is exuded to get it into this pellet form. The first two pairs of legs gain a hold on the little wall round the mouth of the tube, while the pedipalps help to put the pellet into place. The spider continues to bring up pellet after pellet which are of the same size and seem to be fitted into place by the pedipalps. After the placing of each pellet the spider turns round and with the spinnerets uppermost lines the completed part with silk. As more pellets are incorporated this gradually takes the form of a door, and every now and then the spider will pull on this from the inside and shut it, then

push it up again and continue to add to it in a half-closed position. The moving up and down will cause the door to crack in a straight line near the edge of the opening, but as this is reinforced with the silk lining it will not separate from the side of the burrow but will form an admirable hinge. When the door is almost large enough to cover the opening it remains shut, and is completed to the exact requirements from inside. This finished, the spider usually adds more silk round the mouth of the tube. In the case observed the door measured 1 mm. in diameter and the time taken for the excavation and construction was 2¼ hours. Another young spider took 2½ hours to complete the nest.

If the trap-door of a *Migas* nest is opened it will remain so (cf. *Arbanitis gilliesii*) until the spider shuts it. To do this it runs up the back of the burrow across the hinge and its weight shuts the door. The spider can hold the door shut by getting a firm grasp on it with the fangs and tarsal claws of the palps and first two pairs of legs. This makes the door extremely difficult to open and if forced often means the tearing of the door before the spider relaxes its hold. The male spiders are not uncommon and are smaller than the females with longer legs. They make their own trapdoor nests and live on after the breeding season. In the burrowing Mygalids food remains may be deposited inside the burrow as in *Arbanitis* or outside the burrow as is the rule in *Migas spp.* The nests are usually on a bank or tree, and the debris when it is carried to the door will roll away from the mouth of the nest.

Eggs and early stages of *M. distinctus* were collected from December to March. The cocoons are attached to the side of the burrow near the base. The diameter of the egg is 1·0 mm., and 20 to 30 pinkish-yellow eggs are found in each cocoon. About a month after laying the spiderlings hatch, and these moult within a few days. The first instar spiders are inactive and unpigmented. The second moult occurs in just less than a month to produce the active second instar spider which has a bright pink abdomen and is pigmented. In natural conditions this moult takes place in the cocoon within the mother's burrow. It is probable that at this stage she tears open the cocoon and allows the escape of the young, which remain in the nest with her for a short time. Here they are often to be found in the day-time sitting near the opening and showing a decided liking for light. Soon they leave the maternal nest and dig their own burrows.

To test the method by which the young are distributed four spiders which had just emerged from the mother's nest were placed on some soil in a jar which was put in a bowl of water to prevent them leaving the soil. A stick was placed standing up in the soil and a slight draught was allowed to pass over the jar. It is well known that young Araneomorph spiders distribute themselves by climbing up a branch and setting sail from it on a silken thread. Of these four spiders only one so much as went near the stick, and it climbed up only about ½ an inch and then came down. The spiders made for the edge of the jar and eventually settled down and began digging their burrows which took up to 2½ hours to complete. This would indicate that Mygalomorph spiders do not distribute themselves on gossamer threads as do the Araneomorphs.

The pink colour of the abdomen is gradually lost after the spider has been in the burrow for a while, and soon it has the typical adult appearance with dark legs and cephalothorax and a rounded dark abdomen.

Distribution.

The very method of distribution which excludes the use of gossamer for floating on air currents will serve to keep the spiders within near range of one another. This method, or lack of method in spreading themselves seems to be the main limiting factor in their distribution. *Migas distinctus* has been collected from the Otago Peninsula and as far north as Shag Point, Palmerston. It appears to be a typically coastal species. Gatenby (1911) reports it from Wellington, and this range can be further extended to Mokohinou Island, where Goyen found his *M. sandageri*.

Migas taierii n.sp.

The holotype is placed in the Otago Museum.

Female.

Cephalothorax: Varied from a reddish brown to a greyish brown colour. Fovea recurved.

Abdomen: Light brown with a darker pattern.

Chelicera: Three large teeth on inside of groove. Four smaller ones on outside.

Maxilla: Lightly spined. (Pl. 55, Fig. 12.)

Labium: Lightly spined anteriorly.

Sternum: Pale straw-colour. Blunt triangular shape. Two sigillae. (Pl. 55, Fig. 12.)

Venter: Pale brownish yellow. Cream colour round the lung-books and genital operculum.

Eyes: f.r. recurved (sometimes almost straight). h.r. recurved. f.m.e. x 1 diameter apart and x 1½ to 2 diameter from f.l.e. The h.l.e. x ½ diameter of f.l.e. and x 1 diameter from f.l.e. The h.m.e. are of pearly lustre adjoining the h.l.e. (Pl. 56, Fig. 38.)

Tarsal claw: Three to four pectinations on superior claws. (Pl. 57, Fig. 51.)

Dimensions: Average length 14·0 mm. cl. = 6·0 mm., 5·0 mm., 6·0 mm., 5·5 mm. cb. = 5·0 mm, 5·0 mm., 5·5 mm., 5·0 mm. al. = 9·0 mm., 8·0 mm., 8·5 mm., 9·0 mm. ab. = 6·5 mm., 6·0 mm., 7·0 mm., 6·5 mm.

The species differs from *M. distinctus* in the following ways:—

1. General size, colouring and appearance.
2. Smaller number of spines on labium and maxillae.
3. Shape of sternum.
4. Eye arrangement. Distance from f.l.e. to f.m.e.
5. One spine on metatarsus II (cf. *M. distinctus,* two spines on metatarsus II).

   Two spines on metatarsus IV (cf. *M. distinctus,* four spines on metatarsus IV).

Male.

Cephalothorax: Light pinkish brown—darker brown from fovea forward to ocular region. Fovea very recurved.

Abdomen: Small. Fawn with darkish brown pattern.

Chelicera: Three large teeth on inside of groove, four small ones on outside.

Palp: Bulb of palpal organ tapering to a curved pointed tip. Six to eight stout bristles borne on tarsal joint proximal to bulb. (Pl. 58, Fig. 60.)

Leg I: Tibia bearing spur on outside edge.

Maxilla: No spines. Short scopula of bright orange hair anteriorly. (Pl. 55, Fig. 16.)

Labium: No spines.

Sternum: Two sigillae. (Pl. 55, Fig. 16.)

Venter: Pale brown. Very pale lung books and genital operculum.

Eyes: f.r. recurved. h.r. recurved. The f.m.e. less than (x $\frac{1}{2}$–x $\frac{3}{4}$) diameter apart and x 1 from f.l.e. The h.l.e. x $\frac{1}{2}$ f.l.e. and x $1\frac{1}{2}$–2 from f.l.e. The h.m.e. of pearly lustre x $\frac{3}{4}$ f.l.e. and practically adjoining these.

Dimensions: cl. = 4·0 mm. cb. = 4·0 mm. al. = 4·0 mm. ab. = 2·5–3·0 mm. (cf. *M. distinctus* cl. = 3·0 mm. cb. = 3·0 mm. al. = 3·5 mm. ab. = 2·0 mm.)

Legs without coxal joint 4.1.2.3. (cf. *M. distinctus*) I. 13·0 mm., (11·0). II. 12·0 mm., (10·0). III. 10·0 mm., (8·5). IV. 14·0 mm., (11·5).

Migas taierii male differs from that of *Migas distinctus* in its larger size, lighter colouring, eye arrangement. There is very little difference in the palpal organ, though there appear to be more bristles on the palpal tarsus in *M. taierii*.

The proposed name for the species, *Migas taierii* is after the restricted locality in which it is to be found at Taieri Mouth (Dunedin).

Biology.

M. taierii lives on sandy banks in trap-door burrows which are lined with a coarse silk. The average depth of the tube is $3\frac{1}{2}$ inches, and the diameter from 10 0–15·0 mm.

Eggs of *M. taierii* were collected from November to March and all stages from the earliest were observed. The number of eggs in the cocoon varies but is always many more than in *M. distinctus*. Three that were counted contained 80, 91, and 157 eggs respectively.

A cocoon of eggs at a very early stage in development was collected on the 29th November, 1941. These continued development in moist surroundings at room temperature. The beginning of gastrulation with the development of the ventral segments and the appearance of five limb rudiments was evident by the 5th December, 1941, and became increasingly so with lengthening of the limbs. Three pairs of rudimentary abdominal appendages were noticeable by the 15th December. The process of reversion brought about by growth of the dorsal surface had by this time begun and became more marked until the spiderling was ready to hatch. On the 19th January, 1942, approximately five weeks after the eggs were laid, the spiderling hatched. The spiderling is very smooth, white, hairless, and without eyes. There are traces of segmentation in the abdomen, particularly just anterior to the anal tubercle, where the

remnants of six segments are quite clearly visible. The palpal coxae, the maxillae, have not yet moved to a position anterior to the mouth. Through the dorsal abdominal wall the heart can be seen, and it is interesting to note that this has four pairs of ostia. In the adult the last pair has disappeared to leave three pairs. The legs have the full complement of seven segments. By the 17th January short hairs can be seen underneath the skin, and on 19th January the moult takes place. The first instar spiders are not active, and do not feed. The eyes are present but there is no pigment. Spines are present on the chelicerae, maxillae and legs and the body is covered with fine hairs. A trace of abdominal segmentation is still evident in the presence of one segment in front of the anal tubercle. The spider is normally still within the cocoon at this stage. It executes slow stretching movements of the palps and legs. If it were not for the presence of hair and spines at this stage it might easily be mistaken for an Araneomorph spiderling. By the 2nd February pigment has developed round the eyes, and the pattern on the abdomen is visible. The next moult took place on February 13th. The second instar spiders are very active and hairy, with a pink abdomen patterned in brown. Spines develop on the labium, and there is dense pigmentation round the ocular region and on the dorsal abdomen. It is at this stage that they leave the cocoon and live for a few days in the mother's burrow, before settling down to dig their own nest. Silk is now produced, and the spiders usually trail a drag-line of silk behind them; they can move without doing this, however.

The most critical periods of a spider's life are at the moulting stages between the instars. The moult between the first and second instar was observed on two occasions. A split appears at the front of the cephalothorax and the whole covering separates off from the beneath part, extending back through the pedicle to the abdomen. Then the spider, heaving and pulling, slowly begins to extricate the legs and other appendages, while the skin over the abdomen shrivels and leaves this free to be withdrawn. The process takes about 1½ hours to complete, then the extricated spider remains quite motionless by the empty skin for about three hours. At the end of this time the spider becomes an active second instar form which rapidly becomes more deeply pigmented. Growth is slow, and though not definitely known, it is likely that the spiders take up to two years or more to reach maturity.

Distribution.

M. taierii has been found only in a very restricted region at Taieri Mouth (Dunedin). The nests are on a bank (about 50 yards from the store) right on the beach, and the small nest area is situated just above the high-tide level.

KEY TO THE SUB-FAMILY MIGINAE.

1.	Average length 14.0 mm., with pale abdominal colouring	*M. taierii*	
	Average length 9–12.0 mm., with dark abdominal colouring	..	2
2.	Triangular-shaped sternum. f.r. eyes slightly recurved. f.m.e. x ½ diameter apart	*Migas paradoxus*	
	Hexagonal-shaped sternum. f.r. eyes straight. f.m.e. x 1 diameter apart	*M. distinctus*	

Appendix.

The following is the revised list of New Zealand genera and species of the sub-order Mygalomorphae:—

Arbanitis Koch, 1874.
A. gilliesii (Cambridge, 1877).
A. huttoni Cambridge, 1879.
A. collensis n.sp.
A. marplesi n.sp.
A. dendyi (Hogg, 1901).
Korua gen. nov.
K. wanganuiensis gen. et sp. nov.
Aparua gen. nov.
A. bipectinata gen. et sp. nov.
Porrhothele Simon, 1892.
P. antipodiana (Walckenaer, 1837).
P. huttoni (Cambridge, 1873).
P. avocae n.sp.
Hexathele Ausserer, 1871.
H. hochstetteri. Ausserer, 1871.
H. sandersoni n.sp.
Migas Koch, 1873.
M. paradoxus Koch, 1873.
M. distinctus Cambridge, 1879.
M. taierii n.sp.

Summary.

1. A systematic review with biological and distributional notes has been made on the New Zealand Mygalomorphae. The following new species have been described:—*Arbanitis collensis, Arbanitis marplesi, Korua wanganuiensis, Aparua bipectinata, Porrhothele avocae, Hexathele sandersoni* and *Migas taierii.*
2. *Cantuaria dendyi* (Hogg) has been transferred to the genus *Arbanitis,* and is now *A. dendyi. Porrhothele simoni* (Hogg) and *Arbanitis kirkii* (Urquhart) have been placed as synonymous with *P. antipodiana* Simon.
3. Two new genera, *Korua* and *Aparua,* have been established, described and figured. The type species are *Korua wanganuiensis* and *Aparua bipectinata.* The latter is the only member of the sub-family Diplurinae so far described from New Zealand.

Acknowledgment.

The writer wishes to express her thanks to Professor B. J. Marples for suggesting the subject and for his kindly advice and help throughout the paper's preparation.

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* Published a few months after this paper was read, this reference is added here to give a complete literature.

Vol. 74, Part IV, pp. 408–410, Plate 59.

A New Beetle of the Genus *Mecodema*.

By E. Fairburn.

[*Read before the Canterbury Branch, September 3, 1941 (communicated by S. Lindsay); received by the Editor, November 24, 1944; issued separately, March, 1945.*]

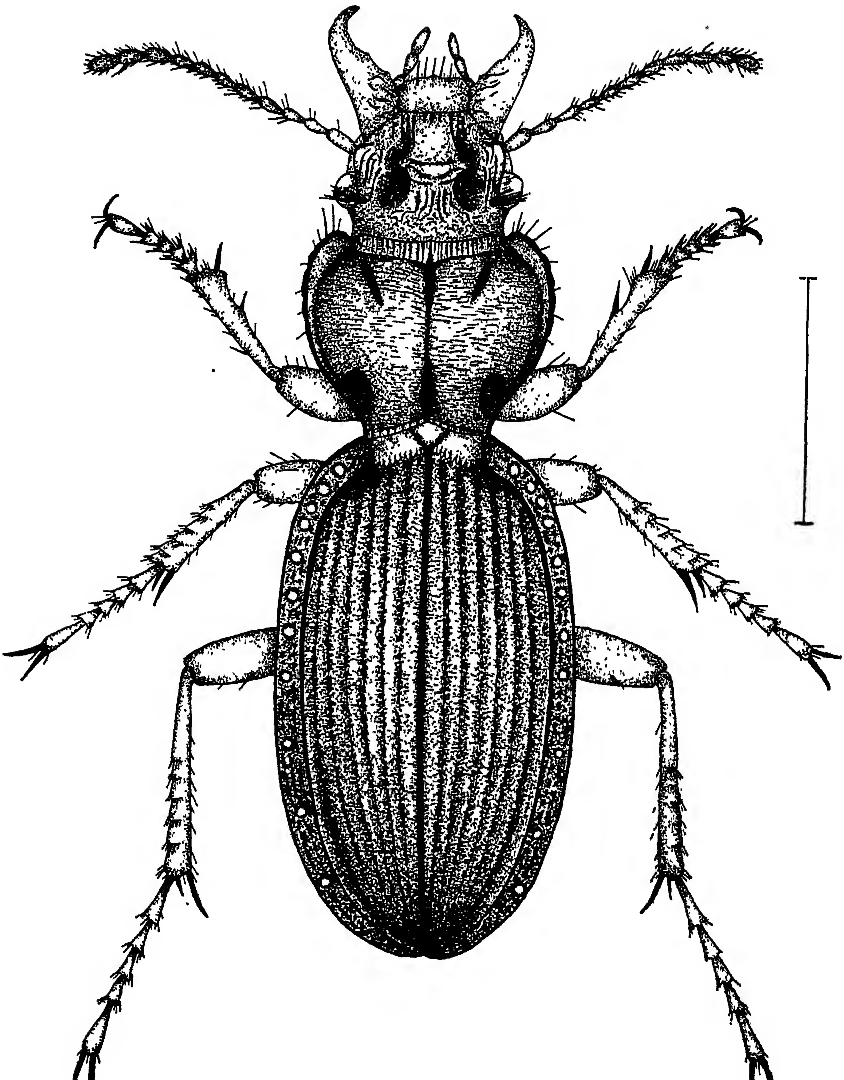
The following addition is proposed to the described beetle fauna of New Zealand:—

Sub-order: ADEPHAGA.
Super-family: Caraboidea.
Family: Carabidae.
Sub-family: Carabinae.

Mecodema allani n.sp. Plate 59.

Moderately elongate and broad; subdepressed. Head, thorax, and underside of body shining black. Elytra dark chocolate colour rather dull. Legs, antennae, and four basal joints of the tarsi dark piceorufus. Apical joints of the antennae and tarsi distinctly paler. Labial and maxillary palpi red, with the apical joints slightly dilate at the apex. Labrum dark red in centre; angles paler. Head, including the prominent eyes, not as wide as the thorax. On the forehead, two large depressions extend from the vertex in a line with the middle of the eyes, to a point a little in advance of the antennal insertion. Each of these depressions is indistinctly divided in two by a slightly raised transverse ridge. The hind depressions are almost circular and contain several conspicuous radiating striae. The front ones are somewhat irregular in shape and almost smooth. From the front edge of each, three rather deep striae proceed longitudinally almost to the front margin of the forehead. There is a similar stria in the centre and several shorter and shallower ones between this and the lateral ones. There are also two or three slightly curved, transverse striae connecting the two hind depressions. The rest of the forehead is raised and smooth with minute punctures. There are several irregular striae on the sides, extending from the inner margins of the eyes to the antennal insertion. There is one setigerous puncture on the inner side of each eye, and one at the base of each mandible. The whole of the back part of the head is coarsely and rugosely punctured, many of the punctures being confluent. Labrum sub-truncate in the centre with well-rounded angles. There are about five long setae along its front margin, and a row of shorter ones on the angles and sides. Mandibles coarsely and obliquely wrinkled for about two-thirds of their length with an obtuse tooth at the base. Antennae pubescent from the fifth joint onward.

Basal four joints shining, the first with one long setae on its upper surface, at about two-thirds of its length. Second with about two, and the third and fourth with several arranged round the apex. Pro-thorax 8¼ mm. wide by 4½ mm. long in the centre. Apex almost subtruncate, being only slightly incurved. Base sinuate, rather strongly incurved at the centre, and with a short sinuation just inside the hind angles, making these project slightly backward. Both the apex and the base have a fringe of ciliae extending right across



J. T. Salmon del.

Mecodema allani Fairburn n.sp.

[*Facing page 408.*]

their margins, central line shallowest in the middle, reaching the base but ending in a well-marked curvate depression behind the apex. Just in front of the middle, and midway between the central line and the margins, there are two large, shallow depressions, one on each side, appearing in some lights to connect with the outer ends of the frontal depression. The sides of the pro-thorax are depressed just inside the apical angles, making the marginal channels appear rather wide at this point. Basal depressions large and deep, and dull with dense minutue sculpture. Marginal channels subcrenate and reflexed, with a row of setigerus punctures along their edges. From behind the apical angles which are well rounded, the sides are nearly straight for about half their length, and from thence strongly rounded to the short straight portion in front of the basal angles. The whole surface is covered with faint transverse lines, and there is a row of short longitudinal striae extending almost right across the basal and apical margins. Elytra oval, rather broad, with moderately well rounded sides and only slightly convex. Marginal channels rather wide, reflexed and entire from base to apex with a row of several shining tubercles each with a puncture in its apex. The first, third, and fifth interstices are a little raised and definitely wider than the others. The seventh is conspicuous and defines the disc. It is narrow, sharply raised, and shining, and is thus in marked contrast to the rest of the surface. Between the suture and the seventh interstice, there are six rows of serial punctures. Between the seventh interstice and the marginal channel there are three more rows of coarser sub-serial punctures separated by two more or less interrupted interstices, this sculpture becoming very much coarser and more confused from the shoulders of the elytra nearly to the hind femora. The whole of the surface between the seventh interstices and the suture is covered with minutue sculpture consisting mostly of fine radiating and transverse lines. From the top of the posterior declivity the elytra are, quite opaque and almost smooth, although traces of the serial punctures can be seen almost to the apex. Scutellum triangular, its hind margins raised and smooth, with the central portion deeply depressed. Underside of the head coarsely sculptured with short, mostly transverse rugae, except the gula, which is nearly smooth and shining. Wings of the mentum with finer rugae and a few punctures, tooth rather small.

Prosternum nearly smooth with faint transverse lines and a few scattered punctures. The portion between the anterior coxae deeply grooved in the centre with obtusely raised borders. Flanks of the prosternum closely and coarsely punctured. Mesosternum nearly smooth, rather small and with a deep, curved channel between the intermediate coxae. Metasternum with a deep transverse depression across the centre. The front half obtusely raised, with a sharp projection between the intermediate coxae. Hind part nearly flat with a fine longitudinal stria in the centre. Its whole surface is covered with fine rugae running in different directions. Basal three abdominal segments densely sculptured with fine irregular wrinkles. The apical ones almost free of sculpture and shining. All the segments have a rather large puncture-like depression close to each side.

Legs rather long and slender. Femora with a few large scattered punctures. Tibiae very slightly curved, with fine setae on the lower edge and coarser ones on the upper. Apical spurs straight and moderately well developed. Claws of the terminal tarsal joint long and slender, only moderately curved.

Length, 33 m.m.; width, 10½ m.m.

Described from two specimens of uncertain sex, which were discovered by Dr. R. S. Allan, of Canterbury College, in a beech-clad valley between Mt. Horrible and Mt. Misery, near Cass, Canterbury, on January 19, 1938, and in whose honour I have great pleasure in naming this fine species. Type and paratype in Canterbury Museum; topotypes in my collection.

Note: In *M. laterale* from the Hollyford Valley, which without doubt is the nearest ally, the elytra are quite black, with coarser sculpture on the disc, very much more so near the sides, the seventh interstice being more or less encroached upon by the coarse punctures. The alternate interstices instead of being in the form of slightly raised costae, are flat and hardly different from the others. The longitudinal striae on the front of the head also differ, being more pronounced and more equally spaced without any wide spaces between them. These differences in colour and sculpture are quite consistent in all the specimens of both species which I have examined.

Transactions of the Royal Society of New Zealand 411
Vol. 74, Part IV, pp. 411–418; 2 Text Figs., Plates 60–62.

Some New Zealand Tertiary Cephalopods.

By C. A. Fleming.
(New Zealand Geological Survey.)

[*Read before the Wellington Branch, October 5, 1944; received by the Editor, October 9, 1944; issued separately, March, 1945.*]

Introduction.

Identification of an *Aturia* from the Eocene beds at Pahi, North Auckland, led to an examination of the somewhat scanty nautiloid material from other localities and horizons in the Geological Survey collections. Early Tertiary nautiloids have been the subject of intensive study in the past few decades in America; and it was hoped that New Zealand members of the group might show affinities which would help in the correlation of local Tertiary stages with extra-limital stratigraphic units.

Two species of *Aturia* and a species each of *Hercoglossa*, *Nautilus* and *Argonauta* are herein described.

TETRABRANCHIATA.

Aturiidae.

In a recent paper, Teichert (1944), in differentiating two Australian species of *Aturia* and defining the characters and distribution of *A. australis* McCoy, expressed doubt as to the occurrence of that species in New Zealand. *Aturia* has been recorded from Eocene, Oligocene and Miocene rocks in New Zealand, but no critical examination of the material has hitherto been made, and the names *A. ziczac* (Sowerby) and *A. australis* McCoy have been used without question.

The Geological Survey collection includes about 16 specimens of *Aturia*, mainly fragmentary or crushed, which fall into two groups, both morphologically and stratigraphically. The genus ranges from Bortonian (mid-Eocene) to Tongaporutuan (Upper Miocene) in New Zealand, and the two groups represented come from either end of this range. No Oligocene examples have been studied, though the Wharekuri specimen figured by Hamilton (1903, plates 37, 38) is of that age.

The Eocene specimens examined are all *Aturia* and not *Aturoidea*, judging from the position of the siphuncle upon the dorsum and from the disposition of the lateral lobes of the sutures.

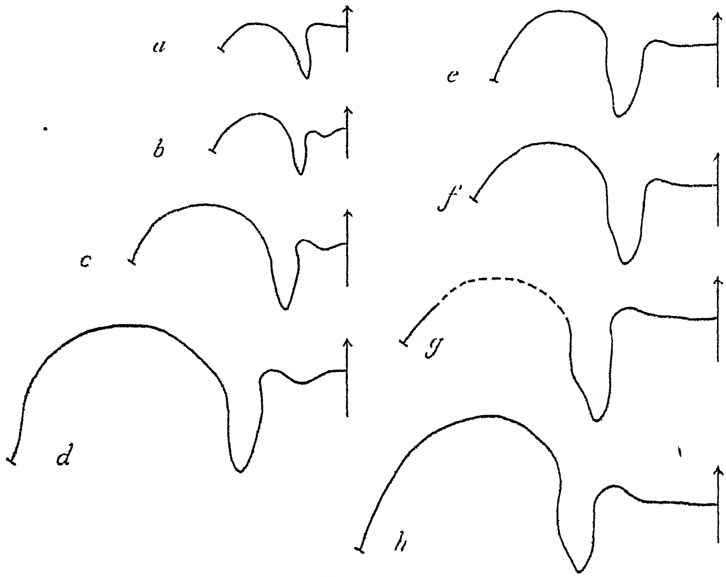
Genus Aturia Bronn.

Subgenus Aturia (s.str.).

Aturia (Aturia) grangei n.sp. (Plate 60, Figs. 1, 2, 3; Text Fig. 1, b, c, d.)

Holotype: A complete shell, somewhat crushed, very large, discoidal, involute. Venter narrowly rounded, flanks slightly compressed in region of lateral lobes, expanding at lateral saddles and widest at umbilical shoulder, giving a narrowly trigonal whorl section, with the lateral zones converging at about 24°. Sutures (Text Fig. 1, c, d) convex towards mouth across venter, a broad shallow

ventrolateral lobe and a well-defined deep obliquely directed saddle at the ventral corner of the base of the lateral lobe. Lateral lobe rapidly tapering, narrow, dorsal limb sweeping forward into an evenly arched lateral saddle. Sutures crowded orally so that tip of a lateral lobe enters preceding lobe, but less so on preceding whorl where tip fails to reach ventral corner of base of preceding lobe.



TEXT FIG. 1.

External suture lines of *Aturia*.

(a.) *A.* (*Aturia*) cf. *australis* McCoy (G.S. 3312).
(b.) *A.* (*Aturia*) *grangei* n.sp. (Paratype A, G.S. 1917).
(c.–d.) *A.* (*Aturia*) *grangei* n.sp. (Holotype, G.S. 3328).
(e.) *A.* (*Brazaturia*) *mackayi* n.sp. (Holotype, G.S. 480).
(f.–g.) *A.* (*Brazaturia*) *mackayi* n.sp. (Paratypes, G.S. 544).
(h.) *A.* (*Brazaturia*) *mackayi* n.sp. (Paratype, Hampden).

All figures half natural size.

Paratype A: (G.S. 1917) An incomplete but undistorted phragmocone showing narrowly trigonal whorl section, and suture line with similar ventral complexity and narrow lateral lobes (Text Fig. 1, b). The last septum is closely similar to that of *A. australis* McCoy, and has the deep wide-mouthed septal invagination of *Aturia* s. str.

Paratype B: (G.S. 3329) A badly crushed internal cast with suture lines showing the same ventral crenulation as the above.

Localities: G.S. 3328, Rangi S.D., Mokau Series (holotype, collected by Dr. L. I. Grange); G.S. 1917, Whareorino S.D., Mohakatino Series; G.S. 3329, Aria S.D., Mohakatino Series.

Remarks: The Mokau beds are at present considered Awamoan (Mid-Miocene, Finlay and Marwick, 1940, p. 120) and the overlying Mohakatino Series is somewhat younger. Specimens of *Aturia* from higher horizons (G.S. 1115, 1119, Mimi S.D., Tongaporatuan Stage, Early Upper Miocene) are the last appearance of the genus

in the Tertiary of New Zealand and are very small shells (altitude, 50 mm.) badly crushed and lacking diagnostic features. The only specimen seen from a lower horizon in the Miocene is from G.S. 3312, Coral Point, Hukatere S.D., the same horizon as Pakaurangi Point beds, high in the Waitemata Series, which are correlated on microfaunal evidence with zones high in the Lower Miocene in the Australian Janjukian (Finlay and Marwick, 1940, p. 95), and with the Upper Aquitanian-Lower Helvetian. The specimen from G.S. 3312 has a simpler ventral suture than *grangei* (Text Fig. 1, a) and thus approaches *australis*, but is more compressed than a Muddy Creek specimen of the latter species available for comparison. Unfortunately the shell is too incomplete for description.

Subgenus BRAZATURIA Stenzel.

Type (original designation, Stenzel, 1935); *Aturia (Brazaturia) brazoensis* Stenzel (Middle Eocene, Texas).

Aturia (Brazaturia) mackayi n.sp. Plate 60, Figs. 4, 5, 6, 7, Text Fig. 1, e–h).

Holotype: G.S. 480. "Island Sandstone," Waihao Valley, South Canterbury.

An incomplete phragmocone with early whorls crushed. Shell involute, lenticular, cross section of whorl broadly rounded at venter, with flat or very slightly convex sides, widening dorsally toward well-defined umbilical shoulder. Lateral zones converging at about 32° in latest stage on specimen. Sutures (Text Fig. 1, e) almost straight across venter, small shallow saddles at ventral base of lateral lobes. Lateral lobes broad, gradually tapering at first, but somewhat pinched in toward the point, with slight ventrally directed kink where they join the somewhat unevenly arched lateral saddles. Tip of lateral lobe touching ventral oral corner of preceding lobe.

Paratypes A, B: G.S. 544, Pahi, Hukatere S.D. Incomplete phragmocones; cross sections more ovate (less trigonal) than holotype, with convex sides. Sutures (Text Fig. 1, f, g) similar to holotype but lateral lobe barely touching corner of preceding lobe. One Pahi specimen is broken along a septum to show a cross section and septal details (Plate 60, Fig. 6) markedly different from those of *A. australis* McCoy and *A. grangei* n.sp. which are assumed to represent *Aturia* s.str. The septum is broadly concave anteriorly and sharply retracted into the lateral funnels. The septal funnel is narrow and shallow, and the siphuncle is subdorsal, adjoining the dorsum, so that, in cross section, the tube rides upon the venter of the preceding whorl.

Paratypes C: Hampden. Several crushed specimens and fragments, one with estimated altitude of 250 mm: and suture as illustrated (Text Fig. 1, h), another with altitude of 220 mm., too badly crushed to show the suture, but with the wide siphuncular tube preserved. The latter consists of a series of connected funnels not greatly contracted at each septum (Plate 60, Fig. 7).

Dimensions: See table below.

Localities: G.S. 480, Waihao Valley (holotype, collected by A. Mackay, 1880); Hampden; G.S. 544, Pahi. All localities are of Bortonian age.

Remarks: The Pahi specimens have a different cross section from the holotype and may represent a different species, but further division is undesirable without better material. It should be noted that the allocation to *Brazaturia* is based on paratypes alone, but the holotype has a similar suture, and comes from a horizon certainly not higher than Bortonian, so that it is likely to belong to the same subgenus, which, as Stenzel (1935, p. 556; 1940, p. 765) has shown, includes most Eocene Aturias. It is also to be noted that the oral sutures of the holotype are crowded, suggesting maturity, whereas the larger Pahi shells may still be immature, judging from their uncrowded chambers.

Brazaturia has been recognised in America (Stenzel, 1935, 1940) from the Jackson group (Bartonian*), Claiborne group (Lutetian–Auversian), and in addition the Californian species *myrlae* Hanna and *kerniana* Anderson and Hanna from the La Jolla (Lutetian) and Tejon formations (Bartonian) are apparently to be included in the subgenus. The recognition of the subgenus in New Zealand is, therefore, in accord with other evidence of the mid-Eocene (Ypresian-Lutetian) age of the Bortonian stage.

Dimensions of New Zealand Aturia in Millimeters.

	A. mackayi n.sp.			*A. grangei* n.sp.	
	Type			Type	
Locality	480	544	544	3328	1917
Maximum diameter (= altitude)	84	—	—	206	—
Height of outer whorl	60	80	92	123	—
Median height	—	48	—	75	—
Height of preceding whorl	—	32	—	48	—
Width of preceding whorl	25	—	—	25	22
Width of outer whorl	46.5	44	—	54	42
Width of lateral lobe at base	11.2	17	17	13	5
Height of whorl at lobe measured	55	77	75	91	33
Width of lobe as percentage of height of whorl	20.4	22.1	22.8	15.4	15.1

HERCOGLOSSIDAE.

Genus HERCOGLOSSA Conrad, 1866.

Type: (by subsequent designation, Hyatt, 1883) *Nautilus orbiculatus* Tuomey, Alabama (Basal Midway Group, Paleocene).

Hercoglossa innominanda n.sp. (Plate 60, Figs. 8–10; Plate 61, Figs. 12–15.)

Holotype: An incomplete cast from a calcareous concretion with fragmentary shell material adhering, somewhat dorsoventrally crushed; shell large, subglobular; adoral whorl expanded, alate; ventral margin broadly rounded; whorls apparently dorsoventrally depressed. One suture line is exposed and shows the broad ventral saddle and deep lateral lobe characteristic of the genus.

Paratype A: Adoral portion of a crushed phragmocone with external shell and external sutures preserved. Outer surface lacking ornamentation, with well-marked growth lines disposed in a shallow hyponomic sinus. Suture with broadly rounded ventral saddle and deep rounded lateral lobe, but lacking the dorsal limb of the lateral

* The European equivalents of Californian Eocene formations quoted in this paper are taken from Clark and Vokes (1936), and those of Eastern United States formations from Roy and Glockzin (1941).

saddle. Whorl shape apparently dorsoventrally depressed, but shell crushed.

Paratype B: A portion of the walls and septa of three chambers of a shell with lensoid cross section certainly due to crushing in incompetent glauconitic mudstone sediments. Only the internal surface of the chambers and an incomplete mould therefrom are exposed. The external suture (Plate 60, Fig. 10), clearly indicated by the intersection of septa with chamber walls, is sinuous and nautiliform, with a broad somewhat flattened ventral saddle, a deep rounded lateral saddle, a deep rounded lateral lobe, and a high narrow lateral saddle, representing an acutely angled, forwardly directed funnel in the septum towards the umbilical region. The ventral saddle is probably not as broad as drawn, as the mid-ventral line is difficult to locate owing to crushing and damage.

Dimensions: (holotype), altitude, 96; height of outer whorl, 51; width of outer whorl, 66; of preceding whorl, 37 mm.

Paratype A: Length of fragment, 62; maximum width, 37 mm.

Paratype B: Height of outer whorl, 35 mm.

Locality: Hampden Beach (Bortonian stage).

Remarks: The sutures of all specimens forbid comparison with any nautiloid genus other than *Hercoglossa*, and are so close to sutures of species of that genus illustrated by Miller and Thompson (1933), Miller (1935), Vokes (1937), and Stenzel (1940) that the generic placing is made with some confidence. More than one species may be represented by the three specimens—there is some variation in sutural detail, as figured—but for the present the recognition of the genus in New Zealand is more important than the number of species.

H. innominanda is apparently one of the less advanced species of the genus lacking the laterally compressed form of more typical *Hercoglossa* and retaining to some extent the subglobular shell of *Cimomia*, which Stenzel (1940) considers ancestral. In detail of suture *innominanda* is close to *H. clarki* Miller from the " Paleocene " of Landana, Portuguese West Africa, but in view of the condition of the New Zealand material, and as there are other named species of which descriptions have not been available for comparison, the similarity has little significance.

The presence of *Hercoglossa* in the New Zealand Bortonian would appear to place an upper limit on the age of the Bortonian. According to Miller and Thompson (1933, p. 313) the genus is " widespread in the Upper Cretaceous and Eocene of Europe, Asia and Africa." Species are present in the Danian, the " Paleocene " Midway of the Atlantic and Gulf Coasts, the Martinez of California and equivalent beds in West Africa. There are fewer records from higher horizons: *H. tuomeyi* C. and M., Nanjemoy formation, Maryland, Lower Eocene; *Hercoglossa* sp. Stenzel, 1940, Texas (Claiborne group, Lutetian); *Hercoglossa cassiniana* Foord and Crick, London Clay (Ypresian); *H. aegyptiaca* Foord, Egypt (Moqattam beds, Ypresian-Lutetian). No upper Eocene examples have been noted in literature and the genus apparently made its last appearance in the Lutetian. Finlay and Marwick (1937, p. 14) have presented reasons for considering the New Zealand Bortonian to be not later than Bartonian in the European time scale, and the occurrance of

Hercoglossa makes it improbable that it is higher than Lutetian. *Aturia*—as *A. (Brazaturia) mackayi*, n.sp.—is well established in the Bortonian, and this also suggests a Lutetian age, since " it appears well established that the genus *Aturia* appeared first in the Reklaw formation " (Stenzel, 1940, p. 736) of Eastern America (lowest Lutetian, *fide* Roy and Glockzin, 1941). In Western America the earliest *Aturia* is also Lutetian (*A. myrlae* Hanna, from the Domengine), earlier species listed by Schenck (1931) having been removed to *Aturoidea* (Vokes, 1937). In Europe the genus is present in the Ypresian (*A. ziczac* (Sow.), *A. charlesworthi* Foord, London Clay), but no definite records of the genus in earlier stages have been seen.*

The evidence of the Nautiloids confirms other evidence for the mid Eocene age of the Bortonian (Finlay and Marwick, 1940, pp. 87, 93) and suggests, more exactly, equivalence with the Ypresian or Lutetian.

NAUTILIDAE.

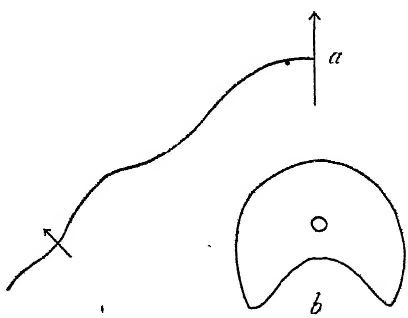
Genus: NAUTILUS Linne, 1758.

Type: *N. pompilius* Linne. Recent.

Nautilus (s.l.) **allani** n.sp. (Plate 62, Figs, 16. 17, 18. Text Fig. 2.)

One incomplete specimen.

Shell large, subglobose, involute, imperforate. External surface with strong growth lines disposed in a hyponomic sinus. Septa extremely convex, with centrodorsally placed siphuncle. Cross section of whorl (Text Fig. 2b) broadly rounded ventrally and laterally, moderately impressed dorsally, umbilical shoulders ill defined. Suture simple (Text Fig. 2), a broad gently arched shallow ventral saddle, a broad shallow assymmetrical lateral lobe and a shallow umbilical saddle. Internal suture simple, with extremely shallow, ill-defined dorsal (annular) lobe. A slight callus, similar to that of Recent *Nautilus*, is developed in the umbilical hollow.



TEXT FIG. 2.

Nautilus (s.l.) *allani* n.sp.

(a.) Suture line.

(b.) Section of chamber to show position of suphuncle.

Half natural size.

* Cossman and Pissaro (1906), Pl. 61, Figs. 5–1' figure a nautiloid as "*A. ziczac* mut, non denommeé," from the Thanetian.

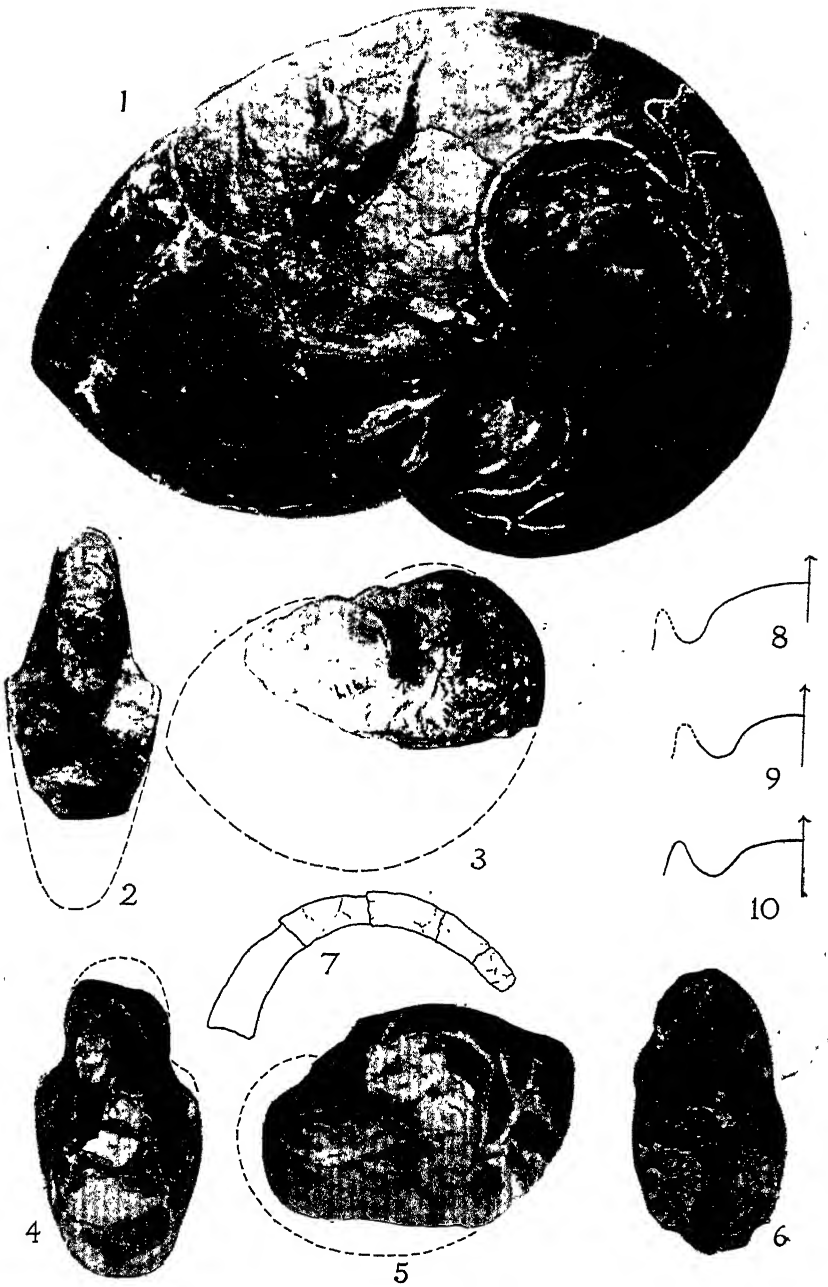


FIG. 1.—*Aturia* (*Aturia*) *grangei* n.sp. (Holotype).
FIGS. 2, 3.—*Aturia* (*Aturia*) *grangei* n.sp. (Paratype, G.S. 1917).
FIGS. 4, 5.—*Aturia* (*Brazaturia*) *mackayi* n.sp. (Holotype).
FIG. 6.—*Aturia* (*Brazaturia*) *mackayi* n.sp. (Paratype, G.S. 544).
FIG. 7.—*Aturia* (*Brazaturia*) *mackayi* n.sp. Siphuncular tube of Hampden specimen.
FIGS. 8, 9, 10.—*Hercoglossa innominanda* n.sp., suture lines. (Holotype Fig. 8.)

(Approximately half natural size.)

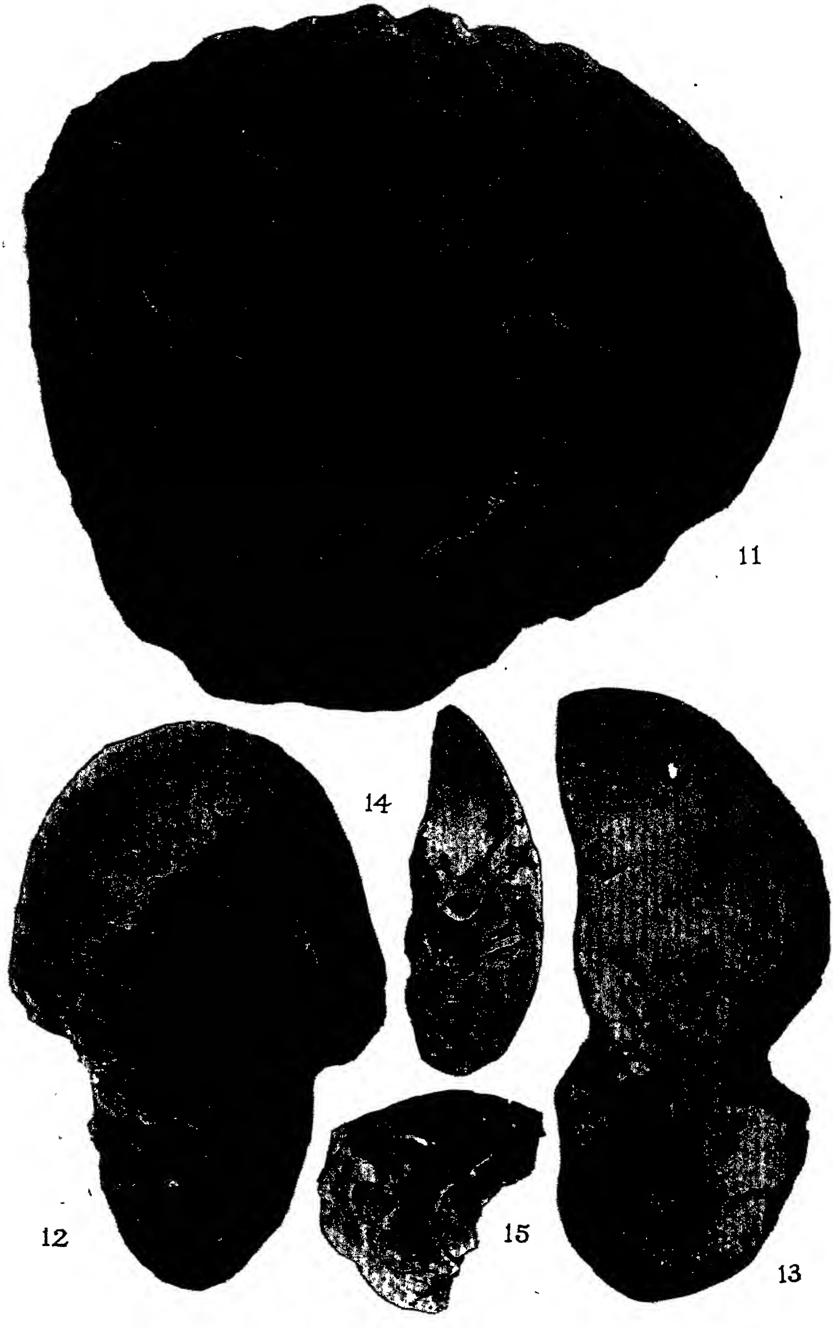
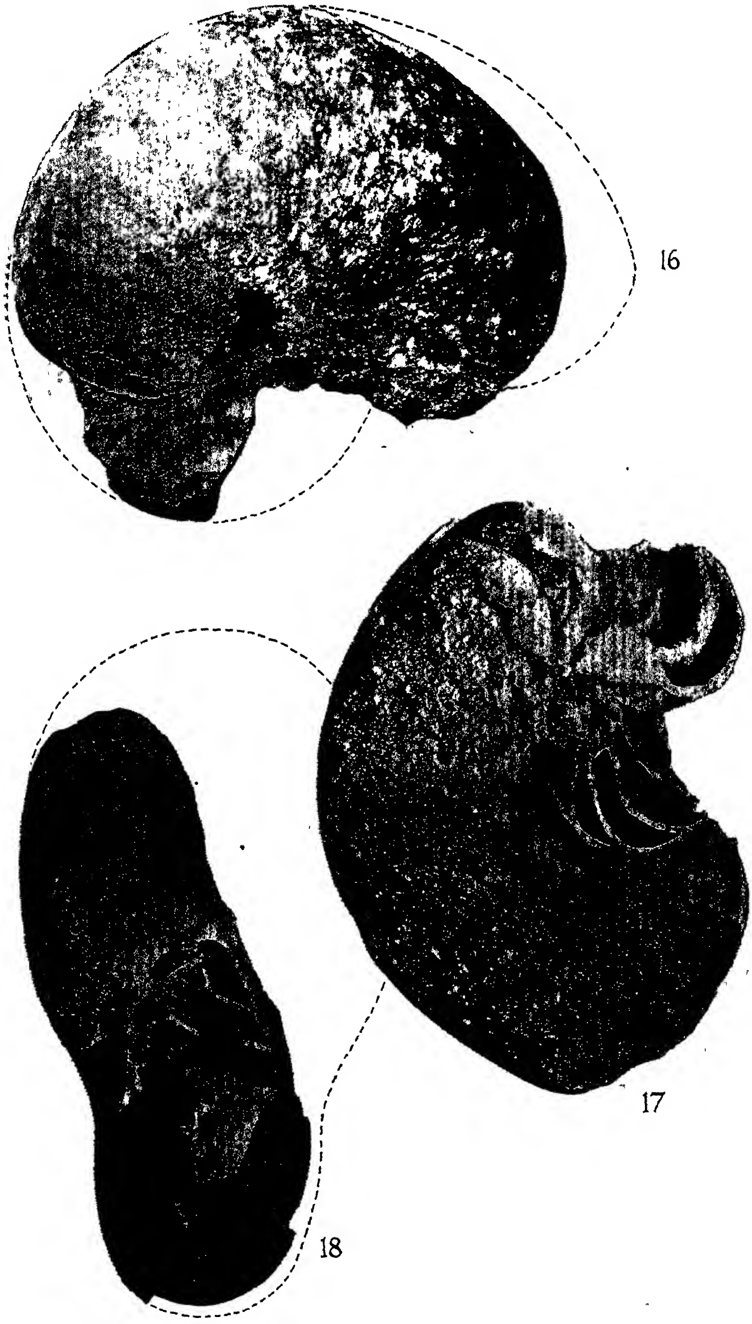


FIG. 11.—*Argonauta oweri* n.sp. (Holotype).
FIGS. 12, 13.—*Hercoglossa innominanda* n.sp. (Holotype).
FIGS. 14, 15.—*Hercoglossa innominanda* n.sp. (Paratypes). Sutures inked.

(Approximately $\frac{4}{5}$ natural size.)



Figs. 16, 17, 18.—*Nautilus* (s.l.) *allani* n.sp. (Holotype).

(Approximately half natural size.)

Dimensions: (Estimated where specimen incomplete); altitude, 193; height of last whorl (living chamber), 120; height of preceding whorl, 77; width of last whorl, 115; width of preceding whorl, 70mm.

Locality: Upper part of coarse tuffaceous limestone, ½ mile south of Wireless Station, Waitangi, Chatham Islands. Collected by Dr. R. S. Allan, Canterbury University College.

Horizon: Marwick (1928, pp. 435–436) noted that the Waitangi and Tioriori beds lack Wanganuian elements present in other members of the Wharekauri–Waitangi Series and are possibly older than upper calcareous tuffs of the same series, which he classified approximately as Early or Middle Tertiary. Some of the upper beds are now regarded as Older Pliocene. In the Waitangi (Waikaripi) bed, the species of *Chlamys*, *Notostrea*, *Venericardia*, *Nemocardium*, and *Perotrochus* have affinities which suggest that the bed is no younger than Upper Oligocene. The affinities of *Nautilus allani* tend to indicate an early rather than mid-Tertiary age for the bed.

Remarks: Generic placing is made without prejudice. The centrodorsal siphuncle, globose, compressed form, and simple suture with ill developed annular lobe, are features foreign to living species of *Nautilus*. *Eutrephoceras* Hyatt includes a number of Jurassic to lower Oligocene species similar in form to *allani;* some species also lack the annular lobe of *Nautilus* and the siphuncle varies in position. The suture of *Eutrephoceras* is described as slightly sinuous or essentially straight externally and "entirely in front of the guide line," but some species at present included in the genus depart from such definitions. Teichert (1943, p. 263) has discussed the position in describing the Australian Eocene *N. victorianus* Teichert, which is similar in several features, including sutural pattern, to *N. allani,* though a much smaller shell. It seems probable that both species would be included in *Eutrephoceras* by some American workers. Their affinities may be closer to aberrant members of that genus, such as *E. bryani* Gabb, Vincentown, New Jersey (Lower Eocene) than *Nautilus*. Both Teichert (op. cit) and Stenzel (1940) suggest that *bryani* is a *Nautilus* (s.l.) rather than a *Eutrephoceras* (s.str.).

DIBRANCHIATA.

ARGONAUTIDAE.

Genus ARGONAUTA Linne, 1758.

According to Spath (1927), "after the Miocene, Nautili almost disappeared, and Aturids became extinct, but Argonauts arose. Of these we now recognise some 20 forms." Davies (1935, p. 356) notes Pliocene occurrences in the Mediterranean and Japan, but the relevant literature is not available and the following New Zealand Pliocene species has been compared only with Recent forms.

Argonauta oweri n.sp. (Plate 61, Fig. 11).

Shell large; whorl section and aperture laterally compressed; though crushed, original shape more like *A. tubercuta* Shaw than other Recent forms, and superficially agreeing with that species in lacking the curved alar processes of *argo* L., *nodosa* Sol., *americana* Dall, etc., but clearly showing affinity to those specialised species rather than to *tuberculata* in the form of the growth lines which are

disposed in a distinct outwardly directed kink, at the point where lip joins body of shell, foreshadowing the alar processes of Recent forms. Sculpture of the *argo* type, i.e., of smooth sinuous radial rugae not divided into tubercles; ridges fairly coarse as in typical *argo* (figured by Reeve, 1842, plate CCC), secondary ridges arising somewhat irregularly but chiefly at outer third of shell. Peripheral nodulation alternating, coarse, tubular, probably cuspate distally.

Dimensions: Altitude, 118; height of aperture, 95; maximum width of aperture (slightly crushed), 40 mm.

Locality: G.S., 2607; limy concretionary boulder in Hautapu River due west of Flat Spur Trig., 1.4 miles south of east from Utiku. Collected by Mr. John R. Ower, Superior Oil Company, and secured for the Geological Survey Collection through the kind offices of Mr. R. E. Turner.

Horizon: Although the specimen was not collected *in situ*, the Hautapu River flows only through Lower Pliocene rocks and the horizon is almost certainly Waitotaran.

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APPENDIX.

For a copy of the Royal Society of New Zealand Act, 1933, and of Rules relating to Admission, Duties, Proceedings, Awards, etc., see *Transactions*, vol. lxv, pp. 468–495.

LIST OF AWARDS.

Award of the Hector Memorial Medal and Prize.

1912. L. Cockayne, C.M.G., Ph.D., F.R.S., F.L.S., F.R.S.N.Z.—For researches in New Zealand botany.

1913. T. H. Easterfield, K.B.E., M.A., Ph.D., F.R.S.N.Z.—For researches in chemistry.

1914. E. Best, F.R.S.N.Z.—For researches in New Zealand ethnology.

1915. P. Marshall, M.A., D.Sc., F.G.S., F.R.S.N.Z.—For researches in New Zealand geology.

1916. Lord Rutherford of Nelson, O.M., D.Sc., F.R.S., F.R.S.N.Z.—For researches in physics.

1917. C. Chilton, M.A., D.Sc., M.B., C.M., F.L.S., F.R.S.N.Z.—For researches in zoology.

1918. T. F. Cheeseman, F.L.S., F.Z.S., F.R.S.N.Z.—For researches in New Zealand systematic botany.

1919. P. W. Robertson, M.A., M.Sc., Ph.D.—For researches in chemistry.

1920. S. Percy Smith, F.R.G.S., F.R.S.N.Z.—For researches in New Zealand ethnology.

1921. R. Speight, M.A., M.Sc., F.G.S., F.R.S.N.Z.—For work in New Zealand geology.

1922. C. Coleridge Farr, D.Sc., F.R.S., F.R.S.N.Z.—For research in physical science and more particularly work in connection with the magnetic survey of New Zealand.

1923. G. V. Hudson, F.E.S., F.R.S.N.Z.—For researches in New Zealand entomology.

1924. D. Petrie, M.A., F.R.S.N.Z.—For researches in New Zealand botany.

1925. B. C. Aston, F.R.I.C., F.R.S.N.Z.—For the investigation of New Zealand chemical problems.

1926. H. D. Skinner, M.A., D.Sc., F.R.S.N.Z.—For research in ethnology.

1927. C. A. Cotton, D.Sc., F.G.S., F.R.S.N.Z.—For researches in the geomorphology of New Zealand.

1928. D. M. Y. Sommerville, M.A., D.Sc., F.R.S.N.Z.—For his general mathematical work and particularly for his investigations in non-Euclidean geometry.

1929. G. M. Thomson, F.L.S., F.R.S.N.Z.—For researches on the acclimatisation of animals in New Zealand and on the natural history of New Zealand fishes.

1930. J. E. Holloway, L.Th., D.Sc., F.R.S., F.R.S.N.Z.—For researches in the life-histories of New Zealand *Pteridophytes.*

1931. W. P. Evans, M.A., Ph.D., F.R.S.N.Z.—For research in pure and applied chemistry.

1932. Te Rangi Hiroa (P. H. Buck), M.D., Ch.B (N.Z.), F.R.S.N.Z.—For researches in Maori ethnology.

1933. W. N. Benson, B.A., D.Sc., F.G.S., F.R.S.N.Z., and J. Marwick, M.A., D.Sc., F.R.S.N.Z.—For researches in New Zealand geology.

1934. G. E. Weatherburn, M.A., D.Sc.—For outstanding original work in mathematics, especially in the use of vector analysis.

1935. W. B. Benham, K.B.E., M.A., D.Sc., F.R.S., F.R.S.N.Z.—For original researches in New Zealand zoology.

1936. W. R. B. Oliver, D.Sc., F.Z.S., F.R.S.N.Z.—For research in New Zealand Botany.

1937. J. R. Hosking, B.Sc., Ph.D.—For research in the chemistry of New Zealand plants.

1938. H. W. Williams, M.A., Litt.D., F.R.S.N.Z.—For researches in ethnology.

1939. J. A. Bartrum, M.Sc., F.R.S.N.Z.—For researches in geology.

1940. D. B. Macleod, M.A., D.Sc., F.R.S.N.Z.—For outstanding work in molecular physics.

1941. H. J. Finlay, D.Sc., F.R.S.N.Z.—For researches on mollusca and foraminifera.

1942. H. H. Allan, M.A., D.Sc., F.L.S., F.R.S.N.Z.—For researches in New Zealand botany.

1943. L. H. Briggs, D.Sc. (N.Z.), D.Phil. (Oxon.), F.N.Z.I.C., F.C.S., F.R.S.N.Z.—For researches in chemistry.

1944. J. C. Andersen, M.B.E.—For researches in ethnology.

Award of the Hutton Memorial Medal.

1911. W. B. Benham, K.B.E., M.A., D.Sc., F.R.S., F.R.S.N.Z.—For researches in New Zealand zoology.

1914. L. Cockayne, C.M.G., Ph.D., F.R.S., F.L.S., F.R.S.N.Z.—For researches in the ecology of New Zealand plants.

1917. P. Marshall, M.A., D.Sc., F.G.S., F.R.S.N.Z.—For researches in New Zealand geology.

1920. J. E. Holloway, L.Th., D.Sc., F.R.S., F.R.S.N.Z.—For researches in New Zealand pteridophytic botany.

1923. J. A. Thomson, M.A., D.Sc., F.G.S., F.R.S.N.Z.—For researches in geology.

1926. C. Chilton, M.A., D.Sc., LL.D., M.B., C.M., F.L.S., F.R.S.N.Z.—For his continuous researches on the amphipodous crustacea of the Southern Hemisphere.

1929. G. V. Hudson, F.E.S., F.R.S.N.Z.—For research in entomology.

1932. J. A. Bartrum, M.Sc., F.R.S.N.Z.—For researches in geology.

1935. G. H. Cunningham, D.Sc., F.R.S.N.Z.—For research in mycological botany.

1938. David Miller, Ph D., M.Sc., F.R.S.N.Z., F.R.E.S., F.L.S.N.S.W.—For researches in entomology.

1941. H. H. Allan, M.A., D.Sc., F.L.S., F.R.S.N.Z.—For botanical researches.

1944. W. N. Benson, D.Sc., F.R.S., F.R.S.N.Z.—For researches in New Zealand geology.

GRANTS FROM THE HUTTON MEMORIAL RESEARCH FUND.

1919. Miss M. K. Mestayer £10, for work on the New Zealand mollusca.

1923. Professor P. Marshall £40, for study of the upper cretaceous ammonites of New Zealand.

1927. Miss M. K. Mestayer £30, for research on brachiopoda and mollusca.

1928. Dr C. Chilton £50, for research on New Zealand and Antarctic crustacea.

1928. Dr H. J. Finlay £10, for research on New Zealand mollusca.

1932. Dr F. J. Turner £30, for geological expedition to south-west portion of Otago.

1932. Mr C. E. Christensen £25, for collecting hybrid plants at Hanmer.

1932. Mr L. C. King £20, for geological study of Tertiary rocks at Awatere Valley, Marlborough.

1932. Dr O. H. Frankel £25, for cytological research.

1932. Waitemata Harbour Survey Committee £25, for ecological survey of Waitemata Harbour.

1933. Mr G. M. Thomson £30, for preparation of illustrated catalogue of New Zealand crustacea.

1933. Mr K. M. Ruddall £5, for zoological research on Little Barrier Island.

1934. Mr L. C. King £25, for geological research in the Marlborough District.

1934. Messrs R. A. Falla and A. W. B. Powell £40, for research on the molluscan and bird fauna of the Sub-Antarctic Islands of New Zealand.

1934. Dr. W. R. B. Oliver £50, for assistance in publishing a monograph on the genus *Coprosma*.

1935. Dr P. Marshall £40, for purchase of microscope goniometer and field work in connection with mineral "tuhualite" of Mayor Island and the occurrence of the spheroidal granite of Karamea.

1935. Mr H. Service £4 10s, for geological research at the Bluff.

1936. Mr C. O. Hutton, £30, for field study of the metamorphic and intrusive rocks of the Lake Wakatipu region.

1938. Dr. F. J. Turner, £15, to defray cost of cutting oriented sections of Otago schists.

1939. Mr L. E. Richdale, £20, for expenses in connection with the ringing of birds.

1941. Dr. F. J. Turner, £25, for research on the structural petrology of metamorphic rocks in Central Otago and Fiordland.

1941. Dr. S. N. Slater, £10, for work on the poisonous constituents of tutu.

1942. Mr L. E. Richdale, £40, for ornithological research at Stewart Island.

1942. Dr. F. J. Turner, £25, for structural petrology of metamorphic rocks.

1944. Mr. L. E. Richdale, £20, for ornithological research at Stewart Island.

1944. Southland Branch Royal Society of N.Z. £40 towards cost of erecting hut on Whero Island for ornithological observation purposes.

Award of the Hamilton Memorial Prize.

1923. J. G. Myers, D.Sc.

1926. H. J. Finlay, D.Sc., F.R.S.N.Z., and J. Marwick, D.Sc., F.R.S.N.Z

1934. L. C. King, M.Sc., Ph.D.

1937. C. O. Hutton, M.Sc., Ph.D., F.G.S., F.M.S.Am.

1943. C. A. Fleming, B.A., M.Sc.

Award of the T. K. Sidey Summer-time Medal and Prize.

1933. Lord Rutherford of Nelson, O.M., D.Sc., F.R.S., F.R.S.N.Z. Special award to Mr G. V. Hudson, F.E.S., F.R.S.N.Z.

1936. Sir Leonard Hill, Kt., M.B., LL.D.

THE ROYAL SOCIETY OF NEW ZEALAND.

COUNCIL FOR 1944–45.

ESTABLISHED UNDER AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND ENTITULED THE NEW ZEALAND INSTITUTE ACT, 1867; RECONSTITUTED UNDER THE NEW ZEALAND INSTITUTE ACT, 1903; CONTINUED UNDER THE NEW ZEALAND INSTITUTE ACT, 1908; AND RECONSTITUTED UNDER THE ROYAL SOCIETY OF NEW ZEALAND ACT, 1933.

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Dr. H. H. Allan, M.A., F.L.S., F.R.S.N.Z.

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Mr. B. C. Aston, F.R.I.C., F.R.S.N.Z. (1944).
Dr. W. R. B. Oliver, F.R.S.N.Z. (1944).
Dr. G. Archey, O.B.E., M.A., F.Z.S., F.R.S.N.Z. (1943).
Lieut.-Col. E. Marsden, C.B.E., F.R.A.S., F.R.S.N.Z. (1943).

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Auckland Institute ..	Mr. A. T. Pycroft. Professor H. W. Segar, M.A., F.R.S.N.Z.
Wellington Branch..	Mr. R. L. Andrew. Dr. L. I. Grange, A.O.S.M., F.R.S.N.Z.
Canterbury Branch..	Dr. R. A. Falla, M.A., F.R.S.N.Z. Dr. O. H. Frankel.
Otago Branch	Dr. C. M. Focken, B.M.E., B.Sc. Dr. F. J. Turner, F.R.S.N.Z.
Hawke's Bay Branch	Mr. G. V. Hudson, F.E.S., F.R.S.N.Z.
Nelson Institute ..	Dr. D. Miller, M.Sc., F.R.S.N.Z.
Southland Branch ..	Professor W. P. Evans, M.A., Ph.D., F.R.S.N.Z., Hon. F.N.Z.I.C.

CO-OPTED MEMBER.

Dr. J. Marwick, F.R.S.N.Z.

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VICE-PRESIDENT: Dr. P. Marshall, M.A., F.G.S., F.R.G.S, F.R.S.N.Z.

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HON. LIBRARIAN: Professor W. P. Evans, M.A., Ph.D., F.R.S.N.Z.

HON. RETURNING OFFICER: Professor H. W. Segar, M.A., F.R.S.N.Z., Hon. F.R.I.C.

SECRETARY: Miss M. Wood, Royal Society of New Zealand, Victoria University College, Wellington, W.1., New Zealand.

MEMBER BODIES.

Name of Society.	Secretary's Name and Address.	Date of Affiliation.
Auckland Institute	Dr. G. Archey, Institute and Museum, Auckland.	June 10, 1868
Wellington Branch of the Royal Society of N.Z.	Mr J. T. Salmon, Dominion Museum, Wellington.	June 10, 1868
Canterbury Branch of the Royal Society of N.Z. ..	Mr. George Guy, Teachers' Training College, Christchurch.	October 22, 1868
Otago Branch of the Royal Society of New Zealand	Dr. H. D. Skinner, Otago Museum, Dunedin.	October 18, 1869
Nelson Institute	Mr. W. C. Davies, Cawthron Institute, Nelson.	December 20, 1883
Hawke's Bay Branch of the Royal Society of New Zealand	Mr. C. F. H. Pollock, P.O. Box 305, Napier.	March 31, 1875
Southland Branch of the Royal Society of New Zealand	Mr. A. D. Nisbet, 264 Dee Street, Invercargill.	October 31, 1939

FORMER MANAGER AND EDITOR
(Under the New Zealand Institute Act, 1867.)

1867-1903.—Sir James Hector, M.D., K.C.M.G., F.R.S.

PAST PRESIDENTS.

1903-04.—Hutton, Captain Frederick Wollaston, F.R.S.
1905-06.—Hector, Sir James, M.D., K.C.M.G., F.R.S.
1907-08.—Thomson, George Malcolm, F.L.S., F.R.S.N.Z.
1909-10.—Hamilton, Augustus.
1911-12.—Cheeseman, Thomas Frederick, F.L.S., F.Z.S., F.R.S.N.Z.
1913-14.—Chilton, Charles, M.A., D.Sc., LL.D., F.L.S., C.M.Z.S., F.R.S.N.Z.
1915.——Petrie, Donald, M.A., Ph.D., F.R.S.N.Z.
1916-17.—Benham, Sir William Blaxland, M.A., D.Sc., F.R.S., F.Z.S., F.R.S.N.Z.
1918-19.—Cockayne, Leonard, C.M.G., Ph.D., F.R.S., F.L.S., F.R.S.N.Z.
1920-21.—Easterfield, Sir Thomas Hill, M.A., Ph.D., F.R.I.C., F.C.S., F.R.S.N.Z.
1922-23.—Kirk, Harry Borrer, M.A., F.R.S.N.Z.
1924-25.—Marshall, Patrick, D.Sc., F.G.S., F.R.S.N.Z.
1926-27.—Aston. Bernard Cracroft, F.R.I.C., F.C.S., F.R.S.N.Z.
1928.——Thomson, J. Allan, M.A., D.Sc., F.G.S., F.R.S.N.Z. (Mr B. C. Aston reappointed May, 1928, *vice* Dr J. Allan Thomson, deceased).
1929-30.—Farr, Clinton Coleridge, D.Sc., F.R.S., F.P.S.L., F.R.S.N.Z.
1931-32.—Segar, Hugh William, M.A., F.R.S.N.Z.
1933-34.—Speight, Robert, M.A., M.Sc., F.G.S., F.R.S.N.Z.
1935-36.—Williams, Rt. Rev. Bishop, M.A., Litt.D. (Cantab & N.Z.), F.R.S.N.Z.
1937-38.—Evans, Prof. W. P. M.A., Ph.D., F.R.S.N.Z., Hon. F.N.Z.I.C.
1939-40.—Holloway, Rev. J. E., L.Th., D.Sc., F.R.S., F.R.S.N.Z.
1941-42.—Archey, Gilbert, O.B.E., M.A., D.Sc., F.R.S.N.Z.

HONORARY MEMBERS.

Elected

Aitken, Alexander Craig, M.A., D.Sc., F.R.S., University of Edinburgh 1940

Andrews, E. C., B.A., F.G.S., 32 Benelong Crescent, Bellevue Hill, Sydney 1934

Buck, P. (Te Rangi Hiroa), M.D., Ch.B. (N.Z.), F.R.S.N.Z., Bishop Museum, Honolulu 1934

Compton, Professor A. H., Ph.D., Sc.D., LL.D., University of Chicago, Chicago, U.S.A. 1934

Diels, Professor L., Ph.D., Director Botanic Garden and Museum, Dahlem, Berlin 1907

Eddington, Sir Arthur Stanley, O.M., Kt., F.R.S., Plumian Professor of Astronomy, Cambridge University 1943

Einstein, Professor Albert, F.R.S., Princeton University, New Jersey, U.S.A. 1924

Fleming, J. A., D.Sc., Director of Department of Terrestrial Magnetism. 5241 Broad Branch Road, N.W. Washington, D.C., U.S.A. 1939

Gatenby, J. B., M.A., Ph.D., B.Sc., D.Sc., Professor of Zoology and Comparative Anatomy, University, Dublin 1934

Hopkins, Sir Frederick Gowland, O.M., M.A., M.B., D.Sc., F.R.S., University of Cambridge 1937

Howard, Lelland O., Ph.D., Sc.D., M.D., LL.D., Onteora Club, Tannersville, New York 1944

Jaggar, Dr T. A., Director of Volcanological Observatory, Volcano House, P.O., Hawaii 1927

Jeans, Sir James H., D.Sc., F.R.S., Cleveland Lodge, Dorking, Surrey .. 1929

Jeffreys, Harold, M.A. (Cantab.), D.Sc. (Durham), F.R.S. Reader in Geophysics, Cambridge University 1943

Jenness, Dr Diamond, M.A., Division of Anthropology, National Museum of Canada, Ottawa 1941

Keith, Sir Arthur, Kt., M.D., F.R.C.S., LL.D., D.Sc., F.R.S., Buckston Browne Farm, Downe, Farnborough, Kent 1939

Marshall, Sir Guy A. K., C.M.G., F.R.S., 16 Cranley Place, London, S.W.7 1933

Mawson, Sir Douglas, B.E., D.Sc., F.R.S., The University, Box 498, Adelaide, South Australia 1920

Millikan, Professor Robert A., Ph.D., LL.D., Sc.D., California Institute of Technology, Pasadena, California 1944

Mortensen, Theodor, Ph.D., Director of the Department of Invertebrates of the Zoological Museum, Copenhagen 1927

Rivett, Sir David, K.C.M.G., M.A., B.Sc. (Oxon), D.Sc. (Melb.), F.R.S., Council for Scientific and Industrial Research, Melbourne 1937

Robinson, Sir Robert, Kt., M.A., D.Sc., F.R.S., The Dyson Perrins Laboratory, South Park Road, Oxford 1939

Russell, Sir John, D.Sc., F.R.S., Director of Rothamsted Experiment Station, Harpenden 1928

Skottsberg, Professor C., D.Sc., Botaniska Tradgarden, Goteborg, Sweden 1938

Smuts, Rt. Hon. Field Marshal J. C., Pretoria, South Africa 1942

Wilckens, Dr. Otto, Bonn University, Bonn 1936

Woods, Henry, M.A., F.R.S., F.G.S., Sedgwick Museum, Cambridge .. 1920

FORMER HONORARY MEMBERS.

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Agardh, Dr J. G.	1900
Agassiz, Professor Louis	1870
Arber, Dr E. A. Newell	1914
Armstrong, Prof. H. E., F.R.S.	1927
Avebury, Lord, P.C., F.R.S.	1900
Baird, Professor Spencer F.	1877
Balfour, Prof. I. Bayley, F.R.S.	1914
Bateson, Professor W., F.R.S.	1915
Beddard, Dr F. E., F.R.S.	1906
Beneden, Professor J. P. van	1888
Berggren, Dr S.	1876
Bowen, Sir George Ferguson, G.C.M.G.	1873
Brady, Dr G. S., F.R.S.	1906
Bragg, Professor Sir William, O.M., K.B.E., F.R.S.	1923
Bruce, Dr W. S.	1910
Butler, Sir Edwin, F.R.S.	1939
Carpenter, Dr W. B., F.R.S.	1883
Chapman, Frederick, A.L.S.	1932
Chree, Dr Charles, F.R.S.	1924
Clarke, Rev. W. B., F.R.S.	1876
Codrington, Rev. R. H., D.D.	1894
Curie, Madame Marie	1927
Darwin, Charles, M.A., F.R.S.	1871
Darwin, Sir George, F.R.S.	1909
David, Professor T. Edgeworth, F.R.S.	1904
Davis, J. W.	1891
Davis, Professor W. Morris	1913
Dendy, Dr A., F.R.S.	1907
Drury, Captain Byron	1870
Ellery, R. L. J., F.R.S.	1883
Etheridge, Professor R., F.R.S.	1876
Ettingshausen, Baron von	1888
Eve, H. W., M.A.	1901
Filhol, Dr H.	1875
Finsch, Professor Otto	1870
Flower, Professor W. H., F.R.S.	1870
Fraser, Sir James G., Kt., O.M., D.C.L., F.R.S.	1920
Garrod, Professor A. H., F.R.S.	1878
Goebel, Professor Dr Carl von	1901
Goodale, Prof. G. L., M.D., LL.D.	1891
Gray, Dr J. E., F.R.S.	1871
Gray, Professor Asa	1885
Gregory, Professor J. W., F.R.S.	1920
Grey, Sir George, K.C.B.	1872
Gunther, Dr A., F.R.S.	1873
Haddon, Dr. A. C., F.R.S.	1925
Haldane, J. S., M.A., M.D., LL.D., F.R.S.	1928
Hall, Sir Alfred D., K.C.B., M.A., D.Sc., F.R.S.	1920
Haswell, Prof. W. A., F.R.S.	1914
Hedley, Charles	1924
Hemsley, Dr W. Botting, F.R.S.	1913
Hill, Sir Arthur W., K.C.M.G., Sc.D., D.Sc., F.R.S.	1928
Hochstetter, Dr Ferdinand von	1870
Hooker, Sir J. D., F.R.S.	1870
Howes, G. B., F.R.S.	1901
Huxley, Thomas H., F.R.S.	1872
Klotz, Professor Otto J.	1903
Langley, S. P.	1896
Lindsay, W. L., M.D.	1871
Liversidge, Professor A., F.R.S.	1890
Lotsy, Dr J. P.	1927
Lydekker, Richard, F.R.S.	1896
Lyell, Sir Charles, F.R.S.	1873
Massart, Professor Jean	1916
McCoy, Professor Sir F.	1888
McLauchlan, Robert	1874
Malinowski, Bronislaw, Ph.D. (Cracow), D.Sc. (Lond.)	1936
Massee, George	1900
Masson, Sir D. Orme, F.R.S.	1928
Mellor, J. W., D.Sc.,	1919
Meyrick, E., F.R.S.	1907
Milne, J., F.R.S.	1906
Mitten, William, F.R.S.	1895
The Most Noble the Marquis of Normanby	1880
Mueller, Dr Ferdinand von, F.R.S.	1870
Muller, Professor Max, F.R.S.	1878
Newton, Alfred, F.R.S.	1874
Nordstedt, Professor Otto	1890
Owen, Professor Richard, F.R.S.	1870
Pickard-Cambridge, Rev. O.	1873
Richards, Rear-Admiral G. H.	1870
Riley, Professor C. V.	1890
Rolleston, Professor G., M.D., F.R.S.	1875
Ross, Sir Ronald	1929
Rutherford, Lord, F.R.S.	1904
Sars, Professor G. O.	1902
Schmidt, Professor J.	1930
Sclater, Dr P. L., F.R.S.	1875
Seward, Sir Albert, F.R.S.	1928
Sharp, Dr D.	1877
Sharp, R. B., F.R.S.	1886
Stebbing, Rev. T. R. R., F.R.S.	1907
Stokes, Vice-Admiral J. L.	1872
Tenison-Woods, Rev. J. E.	1878
Thiselton-Dyer, Sir W. T., F.R.S.	1894
Thomson, Prof. Wyville, F.R.S.	1874
Thomson, Sir Arthur	1928
Thomson, Sir William, F.R.S.	1883
Tillyard, R. J., F.R.S.	1935
Wallace, Sir A. R., F.R.S.	1885
Weld, Frederick A.	1877

FELLOWS OF THE ROYAL SOCIETY OF NEW ZEALAND.

Original Fellows.

(See *New Zealand Gazette*, 20th November, 1910.)

‡*Aston, Bernard Cracroft, F.R.I.C., F.C.S.
*†‡Benham, Sir William Blaxland, K.B.E., M.A., D.Sc., F.R.S., F.Z.S.
§*Best, Elsdon.
§‡*Cheeseman, Thomas Frederick, F.L.S., F.Z.S.
§‡†*Chilton, Charles, M.A., D.Sc., LL.D., M.B., C.M., F.L.S., C.M.Z.S.
§‡†*Cockayne, Leonard, C.M.G., Ph.D., F.R.S., F.L.S.
‡*Easterfield, Sir Thomas Hill, K.B.E., M.A., Ph.D., F.R.I.C., F.C.S.
§‡*Farr, Clinton Coleridge, D.Sc., F.P.S.L., F.R.S.
§Hogben, George, C.M.G., M.A., F.G.S.
†*Hudson, George Vernon, F.E.S.
‡Kirk, Harry Borrer, M.A.
‡†*Marshall, Patrick, M.A., D.Sc., F.G.S., F.R.G.S., F.E.S.
§‡*Petrie, Donald, M.A., Ph.D.
§*Rutherford of Nelson, Lord, O.M., D.Sc., Ph.D., LL.D., F.R.S.
‡Segar, Hugh William, M.A.
§*Smith, Stephenson, Percy, F.R.G.S.
‡*Speight, Robert, M.A., M.Sc., F.G.S.
§Thomas, Sir Algernon Phillips Withiel, K.C.M.G.. M.A., F.L.S.
§‡*Thomson, Hon. George Malcolm, F.L.S., M.L.C.
§‡†Thomson, James Allan, M.A., D.Sc., A.O.S.M., F.G.S

Fellows Elected.

	Date
*†Allan, Harry Howard, M.A., D.Sc., F.L.S.	1928
Allan, Robin Sutcliffe, M.Sc. (N.Z.), Ph.D.	1940
Andersen, Johannes Carl, M.B.E.	1923
‡Archey, Gilbert, O.B.E., M.A., D.Sc., F.Z.S.	1932
Askew, Henry Oscar, M.A., Ph.D., D.I.C., F.R.I.C., F.N.Z.I.C., F.C.S.	1930
*†Bartrum, John Arthur, M.Sc.	1928
*Benson, William Noel, B.A., D.Sc., F.R.S., F.G.S., F.R.G.S.	1926
*Briggs, Lindsay Heathcote, D.Sc. (N.Z.), D.Phil. (Oxon.), F.N.Z.I.C., F.C.S.	1942
§Brown, J. Macmillan, M.A., LL.D.	1925
*Buck, Peter H. (Te Rangi Hiroa), M.D., Ch.B. (N.Z.)	1925
*Cotton, Charles Andrew, D.Sc., A.O.S.M., F.G.S.	1921
†Cunningham, Gordon Herriot, M.Sc., Ph.D., D.Sc.	1929
Curtis, Kathleen M., M.A., D.I.C., D.Sc., F.L.S.	1936
§Denham, Henry George, M.A., D.Sc., Ph.D.	1933
Donovan, William, M.Sc, F.R.I.C.	1938
‡*Evans, William Percival, M.A., Ph.D., Hon. F.N.Z.I.C.	1930
Falla, Robert Alexander, M.A., D.Sc.	1941
*Finlay, Harold John, D.Sc.	1939
Grange, Leslie Issott, D.Sc., A.O.S.M.	1942
Henderson, John, M.A., D.Sc., B.Sc. (in Engineering)	1929
§Hilgendorf, Frederick William, M.A., D.Sc.	1921
‡†*Holloway, John Ernest, L.Th., D.Sc., F.R.S.	1921
§Kidson, Edward, O.B.E., M.A., D.Sc.	1931
§Laing, Robert Malcolm, M.A., B.Sc.	1922
§Maclaurin, James Scott, D.Sc., F.C.S.	1926
*Macleod, Donald Bannerman, M.A., D.Sc.	1935

* Hector Medallist. † Hutton Medallist. ‡ Past President. § Deceased.

Marsden, Ernest, C.B.E., D.Sc., F.R.A.S.	1922
*Marwick, John, M.A., D.Sc.	1935
†Miller, David, M.Sc., Ph.D.	1931
§Morgan, Percy Gates, M.A., F.G.S., A.O.S.M.	1922
*Oliver, Walter Reginald Brook, D.Sc., F.Z.S.	1927
Park, James, Hon.M.Inst.M.M.Lond., F.G.S.	1921
§Philpott, Alfred, F.E.S.	1930
Powell, Arthur William Baden	1940
Rigg, Sir Theodore, M.A., M.Sc., F.R.I.C.	1932
Seelye, Frederick Thomas, A.O.S.M.	1944
*Skinner, Henry Devenish, M.A., D.Sc.	1927
Smith, Lucy May, M.A., F.L.S.	1944
§Smith, William Herbert Guthrie	1924
§*Sommerville, Duncan McLaren Young, M.A., D.Sc., F.R.S.E., F.R.A.S.	1922
§Tillyard, Robin John, M.A., D.Sc., F.R.S., F.L.S., F.E.S.	1924
§Turner, E. Phillips, F.R.G.S.	1936
Turner, Francis John, D.Sc., F.G.S.	1938
*‡§Williams, Herbert William, Rt. Rev. Bishop, M.A., Litt.D.	1923

* Hector Medallist; † Hutton Medallist; ‡ Past President; § Deceased.

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Brooker, S. G., 6 Koraha Street, Remuera, Auckland, S.E.2.
Brown, A. G., P.O. Box 1812, Auckland.
Brown, Miss E., Kohi, Ascot Avenue, Remuera, Auckland, S.E.2.
Brown, Miss L. M., Bella Vue, Norman's Hill, Onehunga, Auckland, S.E.2.
Brownlee, Mrs G., 445 Remuera Road, Auckland, S.E.2.
Buchanan, K., 79 Victoria Avenue, Remuera, Auckland, S.E.2.
Buddle, H. D., 50 Victoria Avenue, Remuera, Auckland, S.E.2.
Buttle, R., Victoria Arcade, Auckland, C.1.
Clayton, D. L., Kauri Timber Co., Auckland, C.1.
Carr, S. Austin, c/o Austin Carr & Co., Box 667, Auckland.
Caughey, Lieut.-Colonel J. E., Alfred Street, Auckland, C.1.
Clinch, Dr. J. A., 43 Haydn Avenue, Epsom, Auckland, S.E.3.
Coakley, L. J., c/o George Walker, Ltd., Queen Street, Auckland, C.1.
Cocker, Mrs. W., 124 Grafton Road, Auckland, C.2.
Comyns, C. C., P.O. Box 1974, Auckland.
Court, A. H., Queen Street, Auckland, C.1.
Cousins, H. C., "Edgecliffe," 126 Vauxhall Road, Devonport, Auckland, N.1.
Craig, J. C., 67 Mountain Road, Epsom, Auckland, S.E.3.
Crompton, W. J., Carrington Road, New Plymouth.
Crookes, Miss M. W., 31 Maungawhau Road, Epsom, Auckland, S.E.3.
Crookes, S. Irwin, Customs Street, Auckland, C.1.
Dale, T. J., Tennyson Street, Birkenhead, Auckland, N.5.
Davidson, S. L., 33 Mont le Grand Road, Mt. Eden, Auckland, S.2.
Davis, Sir Ernest, Hancock & Co., Ltd., Auckland, C.1.
Dearsley, H. P., P.O. Box 466, Auckland.
de Courcy, Dr. Grace, Market Road, Remuera, Auckland, S.E.2.
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Dignan, F. J., Northern Club, Auckland, C.1.
Dixon, C. E., 69 Yarra Bank Road, South Melbourne, Victoria, S.C.4.
Donald, J. B., P.O. Box 659, Auckland, C.1
Draffin, M K., South British Insurance Buildings, Shortland Street, Auckland.
Duthie, N. A., Williamson Chambers, Shortland Street, Auckland, C.1.

Elliott, Sir George, London.
Eady, A. T., 12 Huntly Avenue, Auckland, C.3.
Ellis, Sir Albert, C.M.G., National Bank Buildings, Shortland Street, Auckland, C.1.
Endean, W. P., Endean's Buildings, Auckland, C.1.
Entrican, J. C., 14 Alexis Avenue, Mt. Albert, Auckland, S.W.2.
Ewen, J. F. A., c/o Sargood, Son & Ewen, Ltd., Auckland, C.1.
Fairclough, Dr. W. A., Imperial Buildings, Auckland, C.1.
Falla, Dr. R. A., Canterbury Museum, Christchurch.
Fielder, F. H. V., 29 Adam Street, Greenlane, Auckland, S.E.4.
Firth, Dr. R., London School of Economics, Houghton Street, London, W.C.2.
Fleming, C. A., N.Z. Geological Survey, 156 The Terrace, Wellington.
Fletcher, J., 21 Upland Road, Remuera, Auckland, S.E.2.
Ford, A. E., Auckland Transport Board, Auckland, C.1.
Ford, C. E., 8 Paice Avenue, Mt. Eden, Auckland, S.2.
Fraser, W. M., Whangarei.
Gardner, C. F., New Lynn, Auckland.
Gentles, J. A., P.O. Box, 1584, Auckland.
George, S. Thorne, Government Life Insurance Buildings, Queen Street, Auckland, C.1.
Gillman, Miss A. M., 34 Grey Street, Onehunga, Auckland, S.E.5.
Goldie, A., Wallace Street, Herne Bay, Auckland, W.1.
Goodfellow, W., 54 Almorah Road, Epsom, Auckland, S.E.3.
Graham, G., Ferry Buildings, Auckland, C.1.
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Gunson. Dr. E. B., Lister Buildings, Auckland, C.1.
Hatch, Corporal D., Waiouru Military Camp.
Henley, Lieutenant J. C., Camp Hospital, Papakura Military Camp.
Hellaby, F. A., Hellaby's Buildings, Auckland, C.1.
Holt, Mrs. J. H., Godley Road, Titirangi.
Hoveli, S.M., Waihi.
Horton, R. C., Princes Street, Auckland.
Hutchinson, A. J., 414 T. & G. Buildings, Auckland, C.1.
Hutchinson, G. W., C.M.G., Premier Buildings, Durham Street, Auckland, C.1.
Iuder, E. W., P.O. Box 1747, Auckland, C.1.
Jackson, Gainor, Anzac Avenue, Auckland, C.1.
Jefferson, Miss C., Waihi Beach.
Jenkins, H. R., Karori Crescent, Orakei, Auckland.
Johnstone, Hallyburton, 56 Albert Road, Avondale, Auckland, S.W.3.
Jones, H. R., c/o J. M. Mennie, Ltd., Auckland, C.1.
Jones, H. K., 21 Wapiti Avenue, Epsom, Auckland, S.E.3.
Keys, L. J., St. Helier's Bay, Auckland, E.1.
La Roche, Mrs. W. E., Howick.
Larner, V. J., Guardian Trust, Shortland Street, Auckland, C.1.
Leys, Sub-Lieutenant T. H., 24 Victoria Avenue, Remuera, Auckland, S.E.2.
Lloyd, Miss Z. O., 2 Nixon Street, Onehunga, Auckland, S.E.5.
Lunn, A. G., 5 Tui Street, Devonport, Auckland, N.1.
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Mandeno, L., 6 Highwic Avenue, Epsom, Auckland, S.E.3.
Mappin, Sir Frank, 119 Mountain Road, Epsom, Auckland, S.E.3.
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Rangi Hiroa, Te, Dr. Bernice P., Bishop Museum, Honolulu, Hawaii.
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Rogerson, H. M., Power Board Building, Auckland, C.1.
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Russell, Miss M. A. N., Omahu Road, Remuera, Auckland, S.E.2.
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Smallwood, T. N., State Advances, Wellington.
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Steen, D. H., P.O. Box 367, Auckland.
Stevens, L. J., Queen's Arcade, Customs Street, Auckland, C.1.
Stevenson, A. G., 32 Pentland Avenue, Mt. Eden, Auckland, S.2.
Stevenson, Miss E. M., 16 Bassett Road, Remuera, Auckland, S.E.2.
Stevenson, Lieutenant J. M., on active service.
Stevenson, R. S., 22 Ngapuhi Road, Remuera, Auckland, S.E.2.
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Sullivan, J. J., P.O. Box 1175, Auckland.
Taylor, Dr. R. M. S., District Health Office, Box 1, Hamilton.
Thomas, N. R. W., 114 Mountain Road, Epsom, Auckland, S.E.3.
Thorburn, G. C., 52 Fort Street, Auckland, C.1.
Thomson, T. C., 4 Takutai Street, Parnell, Auckland, C.4.
Tomlinson, L. H., Electric Construction Co., Fort Street, Auckland, C.1.
Turbott, E. G., Cathedral Place, Auckland, C.4.
Upton, Miss E. M., 35 Bassett Road, Remuera, Auckland, S.E.2.
Upton, P., 247 Remuera Road, Auckland, S.E.2.
Upton, Mrs. Selwyn, 25 Victoria Avenue, Remuera, Auckland, S.E.2.
Walker, A. Howey, Queen Street, Auckland, C.1.
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Wells, T. U., Westbourne Road, Remuera, Auckland, S.E.2.
Williamson, J. W., 57 Clifton Road, Takapuna, Auckland, M.2.
Wilson, W. R., "Herald" Office, Auckland, C.1.
Wilson, Mrs. R. M., 286 Remuera Road, Remuera, Auckland, C.1.
Wilson, Martyn, 82 Shore Road, Remuera, Auckland.
Winstone, G., Box 400, Auckland.
Winstone, F.M., Claude Road, Epsom, Auckland, S.E.2.
Worley, R. P., N.Z. Insurance Buildings, Auckland, C.1.
Wynward, M. H., Cooke's Buildings, Queen Street, Auckland, C.1.
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Yates, E., Albert Street, Auckland, C.1.
Yates, E. W., 707 Remuera Road, Auckland, S.E.2.

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Acheson, Judge F. O. V., Te Kao, North Auckland.

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Anderson, Professor W., University College, Auckland.
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Ah Kew, Henry, Argus House, High Street, Auckland, C.1.
Andrews, Dr. J. C., 119 Market Road, Epsom, Auckland, S.E.3.
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Ashcroft, Miss E. B., 15 St. John's Road, Meadowbank, Auckland.
Asche, Lieutenant D., U.S.N.R., c/o Grand Hotel, Auckland.
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Barfoot, V. H., N.Z. Insurance Buildings, Auckland, C.1.
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